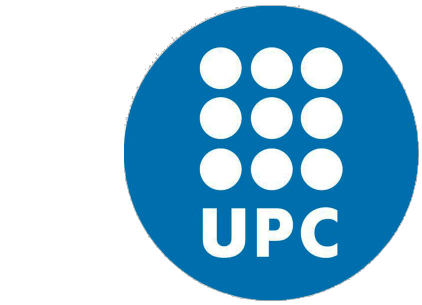
UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

The water-energy-food nexus to tackle climate change in Morocco

by

Laia Barbarà Mir

Doctoral Programme in Sustainability



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Doctoral Thesis

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Laia Barbarà Mir

Thesis Director

Dr. José María Gil Roig

Barcelona, 2020

Image from Unplash

"I love that smell of the emissions." - Sarah Palin, 2012

"The best thing about the Earth is if you poke holes in it oil and gas comes out."
- Republican U.S. Congressman Steve Stockman, 2013

"Our science is a drop, our ignorance a sea" - William James, 1895

"How sad to think that nature speaks and mankind doesn't listen." - Victor Hugo, 1840

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Declaration of Intent

"It is, I promise, worse than you think" (Wallace, 2017). David Wallace's now famous 2017 essay on the realities of climate change informs much of today's focus on stopping and reversing climate change. Globally, nations are paying more and more attention to the concerns and problems that come along with climate change. Humanity is living in the Anthropocene: the world is changing, but more importantly, humanity is what is changing it.

On a positive note, the world is also becoming more aware of the human impact on the earth. Organizations both on the national and multinational levels are taking action to try and halt the coming climate change doomsday. One effort at both tackling climate change and thinking about our future in terms of sustainable consumption is the Water, Energy, and Food Nexus.

Organizations worldwide agree on the fact that our future will end as we understand it today, unless we switch towards a sustainable approach to life. The WEF Nexus is a model that promotes sustainable development in three of the most vital resources. Water, energy and food are central to life. May this Thesis contribute to a universal call to action to end poverty, protect the planet, and ensure prosperity for all people.

Acknowledgement

A number of individuals have been instrumental to my intellectual development and the shaping of this Thesis in various institutions where I have both studied and worked in the recent years.

Particularly, I am most grateful to my Thesis Director, José M. Gil Roig, an agricultural economist and Director of CREDA -the Center for Agro-Food Economics and Development- of the UPC. Professor Gil Roig was persistent in encouraging my work and supporting my intellectual development. I am forever thankful for that most valuable guidance and backing.

I also owe a lot to the prominent individuals in the field that I had the pleasure to meet and who generously contributed to this research work. I thank each and every one of them for having offered me their intellectual support and advice in a number of occasions.

Executive summary

The water, energy and food nexus is a theoretical approach to better understand and systematically examine the interactions between the natural environment and human activities, and to work towards a more organized management and use of natural resources across sectors and scales (FAO, 2014). It looks at the way a group of people -regionally, nationally, and locally- utilize resources and analyzes how they can be more efficiently managed. In implementing the WEF Nexus, there are ripple effects through the 17 Sustainable Development Goals (SDGs). In fact, several governments have already incorporated the WEF Nexus as part of their governmental policy in order to promote a more sustainable future.

The WEF Nexus has four objectives: to help eradicate food insecurity, hunger, and malnutrition; make fisheries, forestry, and agriculture more productive and sustainable; help eliminate rural poverty; and enable efficient and sustainable food systems (FAO, 2019). In order to fully understand the challenges, trends, and opportunities presented by the WEF Nexus, this research covers what it is and where it comes from by studying the interlinks and trade-offs among these three resources; and suggests best practices to relieve the pressures that threaten resource availability and better manage them.

However, problems arise in the implementation of those goals. For example, the rising number of climate migrants indicates that there are still problem areas in achieving the Nexus[1] to its fullest potential. This Thesis also analyzes the current status of the WEF Nexus in these areas and provides policy recommendations for the particular case of Morocco.

Within the MENA region, Morocco is probably the most vulnerable country to climate change: desertification, sea-level rise, groundwater salinization, climate migration as well as sudden flooding and storms affect the life of people in all parts of the country. Such a unique and fragile situation motivated the choice of the country as the case study for this research work.

A WEF approach to managing a country's resources is a great first step towards achieving the targets of the 2030 Agenda. The WEF Nexus is a catalyzing force for development: it underpins equality and democracy whilst setting the foundation to achieve the Sustainable Development Goals. Protecting the world's most vital resources, without which human life is impossible, is the Nexus first priority.

[1] Throughout this Thesis: *Nexus*, *WEF Nexus and WEF,* are used indistinctly to refer to the *Water, Energy and Food Nexus*.

Resumen ejecutivo

El nexo agua, energía y alimento es un enfoque teórico que nos ayuda a comprender mejor y a examinar sistemáticamente las interacciones entre el medio ambiente y las actividades humanas, así como trabajar hacia una gestión más organizada de los recursos naturales en todos los sectores y escalas (FAO, 2014). El WEF Nexus analiza la forma en que un grupo de personas -a nivel regional, nacional y local- utiliza el agua, la energía y los alimentos y estudia cómo pueden gestionarse de manera más eficiente. La implementación del Nexus tiene impacto en los 17 Objetivos de Desarrollo Sostenible (ODS). De hecho, ya son varios los gobiernos que han incorporado el Nexus en su política gubernamental para promover un futuro más sostenible.

El WEF Nexus tiene cuatro objetivos principales: ayudar a erradicar la inseguridad alimentaria, el hambre y la desnutrición; hacer que la pesca, la silvicultura y la agricultura sean más productivas y sostenibles; ayudar a eliminar la pobreza rural; y permitir sistemas alimentarios eficientes y sostenibles (FAO, 2019). Con el fin de comprender las tendencias, desafíos y oportunidades que presenta el WEF Nexus, esta investigación abarca qué es y de dónde proviene mediante el estudio de las interacciones entre estos tres recursos naturales; y sugiere buenas prácticas, para aliviar las presiones que amenazan la disponibilidad de recursos.

Sin embargo, en la implementación de dichos objetivos todavía surgen problemas. Por ejemplo, el creciente número de migrantes climáticos nos indica que todavía hay áreas problemáticas a resolver para que el Nexus alcance su máximo potencial. Esta tesis también analiza el estado actual del Nexus y proporciona recomendaciones para el caso particular de Marruecos.

Dentro de la región MENA, Marruecos es probablemente el país más vulnerable al cambio climático: la desertificación, el aumento del nivel del mar, la salinización de las aguas subterráneas, la migración climática, así como las inundaciones repentinas y las tormentas, que afectan la vida de sus habitantes en todas las partes del país. Una situación tan singular y frágil ante el cambio climático como la de Marruecos fue lo que motivó la elección del país como caso de estudio para esta Tesis.

Administrar los recursos de un país con un enfoque WEF Nexus es un gran primer paso para lograr los objetivos de la Agenda 2030. El WEF Nexus es una fuerza catalizadora para el desarrollo: promueve la igualdad y la democracia a la vez que establece las bases para alcanzar los Objetivos de Desarrollo Sostenible. Proteger los recursos más vitales del mundo, sin los cuales no habría vida humana, es imposible, es la primera prioridad del Nexus.

List of acronyms

A2030	Agenda 2030 (United Nations)
BRIICS	Brazil, Russia, India, Indonesia, China and South Africa
CKP	Climate Knowledge Portal (World Bank)
CO2	Carbon dioxide
EE	Energy Efficiency
EJF	Environmental Justice Foundation
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GWOPA	Global Water Operators' Partnership Alliance
GWP	Global Water Partnership
HDI	Human Development Index
ICT	Intelligent Communication Technologies
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
MCA	Multi-Criteria Assessment
MCM	Million Cubic Meters
MENA	Middle East and North Africa
OECD	Organization for Economic Co-operation and Development

PPP	Public Private Partnership
PV	Photovoltaic
SDG	Sustainable Development Goals
SEI	Stockholm Environmental Institute
UN	United Nations
UN Water	United Nations Water
UNCTAD	United Nations Conference on Trade and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNF	United Nations Foundation
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
UNSTAT	United Nations Statistics Division
US DOE	United States Department of Energy
USAID	United States Agency for International Development
USD	United States Dollar
W4EF	Water for Energy and Food
WB	World Bank
WBCSD	World Business Council for Sustainable Development
WEF Neuxs	Water, Energy and Food Nexus
WEF	World Economic Forum
WEO	World Energy Outlook
WHO	World Health Organization
WWAP	World Water Assessment Programme
WWDR	World Water Development Report

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Chapter 1: Introduction and Thesis Structure

It is of common understanding that sustainable and effective solutions to tackle the challenge of climate change will require a deeper understanding of the interlinkages between water, energy and food resources. Most of these points were captured in the "Perfect Storm" of John Bedington (2009), where increasing resource demands and global population were threatened by resource availability. Addressing these challenges requires new ways of thinking and flexible governance frameworks. In the past years, tackling water, energy and food in a holistic manner has been strongly promoted in the global research agenda as an emerging development paradigm. At the core of the nexus debate lie natural resource scarcities and the recognition that water, energy and food are interlinked through a complex relation where resource use and availability are interdependent (Dupar and Oates 2015; Hoff 2011).

Given that water, energy and food are inextricably linked, the access to these resources as well as their effective management underpins development progress. Water is an input for producing agricultural goods and along the entire agro-food supply chain. Energy is required to produce and distribute water and food: to pump water from groundwater or surface water sources, to power cultivation and irrigation machinery, and to process and transport agricultural goods[2]. As a result of these interdependencies, decision-makers in all sectors face the challenge of accounting for synergies and potential trade-offs between water, energy, food and the environment at multiple spatial and temporal scales (Howells and Rogner 2014).

1.1 Genesis and evolution of the WEF Nexus

Whilst the Water, Energy and Food Nexus was launched more than a decade ago in 2008, it did not receive much interest from the scientific community or the media. It was not until the United Nations Summit in 2015 that the WEF Nexus gained attention and focus due to the development of the SDGs. Through this public notoriety, some nations and organizations have begun implementing WEF practices with great results which might serve as a source for inspiration to other countries.

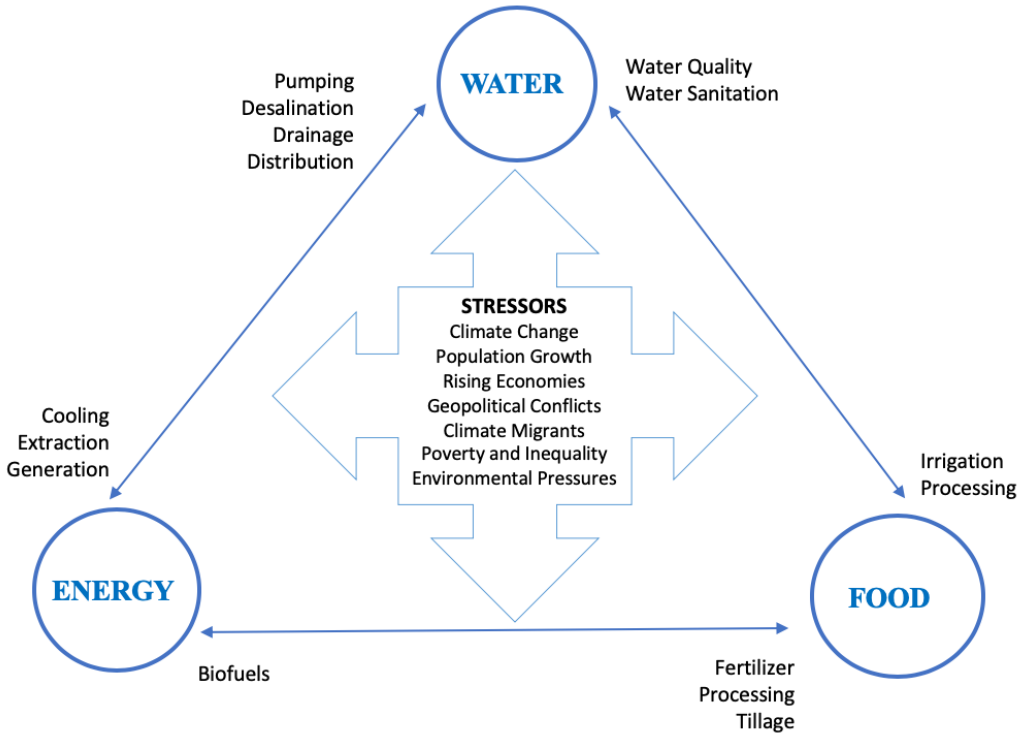
The concept of the WEF Nexus appeared in the international community with regards to climate change, globalization, increasing population and economic growth, urbanization, inequalities and social discontent[3]. The world population is

[2] G. Poyyamoli, 2017. Agroecology, Ecosystems and Sustainability in the Tropics. Studera Press New Delhi. p. 374

[3] Hoff, J. Understanding the Nexus. In Proceedings of the Bonn 2011 Conference: The Water, Energy and Food Security Nexus, Bonn, Germany, 16–18 November 2011.

likely to reach 8 billion by 2025, and 10 billion by 2050[4] and the UN World Population Prospect estimates that 54% of the world population live in urban areas, and this share is expected to increase to 66% by 2050[5]. On the other side, in the developing world, around 1.1 billion people still lack access to clean water[6], and 1.2 billion live in extreme poverty[7]. Such issues put extra pressure on the WEF resources, bringing up a number of trade-offs and potential disputes with complex interlinks among water, energy and food[8]. With the help of Figure 1 below, the first conclusions can be deducted:

Figure 1. Interdependencies and external drivers of the WEF Nexus



Source: own creation.

- Water is a critical input for hydro-power generation and food production;
- Energy costs are a critical input into the costs of irrigation, fertilizer and diesel and thus matter for agriculture;

[4] United Nations Department of Economic and Social Affairs, Population Division (UNDESA). World Population Prospects: The 2012 Revision; UNDESA: New York, NY, USA, 2013; p. 118.
[5] United Nations Department of Economic and Social Affairs, Population Division (UNDESA). World Population Prospects: The 2014 Revision; UNDESA: New York, NY, USA, 2014; p. 27.
[6] United Nations Development Programme (UNDP). Human Development Report 2013; UNDP: New York, NY, USA, 2013; p. 203.
[7] United Nations (UN). The Millennium Development Goals Report 2013; UN: New York, NY, USA, 2013; p. 60.
[8] Front. Environ. Sci. (Frontiersin), 08 Februaryn 2019, https://doi.org/10.3389/fenvs.2019.00008

- People need water to drink, food to eat and energy to power their lives -food and energy can be imported and transported over long distances, water typically cannot;

Water, energy and food security represent an interlinked and increasingly important factor in sustainability. Water is at the center of the nexus; its availability and price determine what is possible in energy and agriculture. Around 80% of the abstracted water is used in irrigated agriculture, which at the same time consumes approximately 1/3 of total energy in rural communities[9]. The growing urban population together with its associated industrialization is rapidly increasing the water demands of villages and cities such that many urban areas are facing severe water-shortages, poor peri-urban potable quality and associated health concerns. Furthermore, the untreated discharge of wastewater is severely polluting both surface and groundwater in many regions of the countries.

1.2 Analytical Gaps

Recently, the WEF Nexus has earned increasing attention in research, business, and international policy spheres. A thorough literature review has been conducted in order to get an overview of the published academic articles, professional journals and newspaper articles, books and book chapters as well as Government and International Organizations reports on matters relevant to the water, energy and food Nexus.

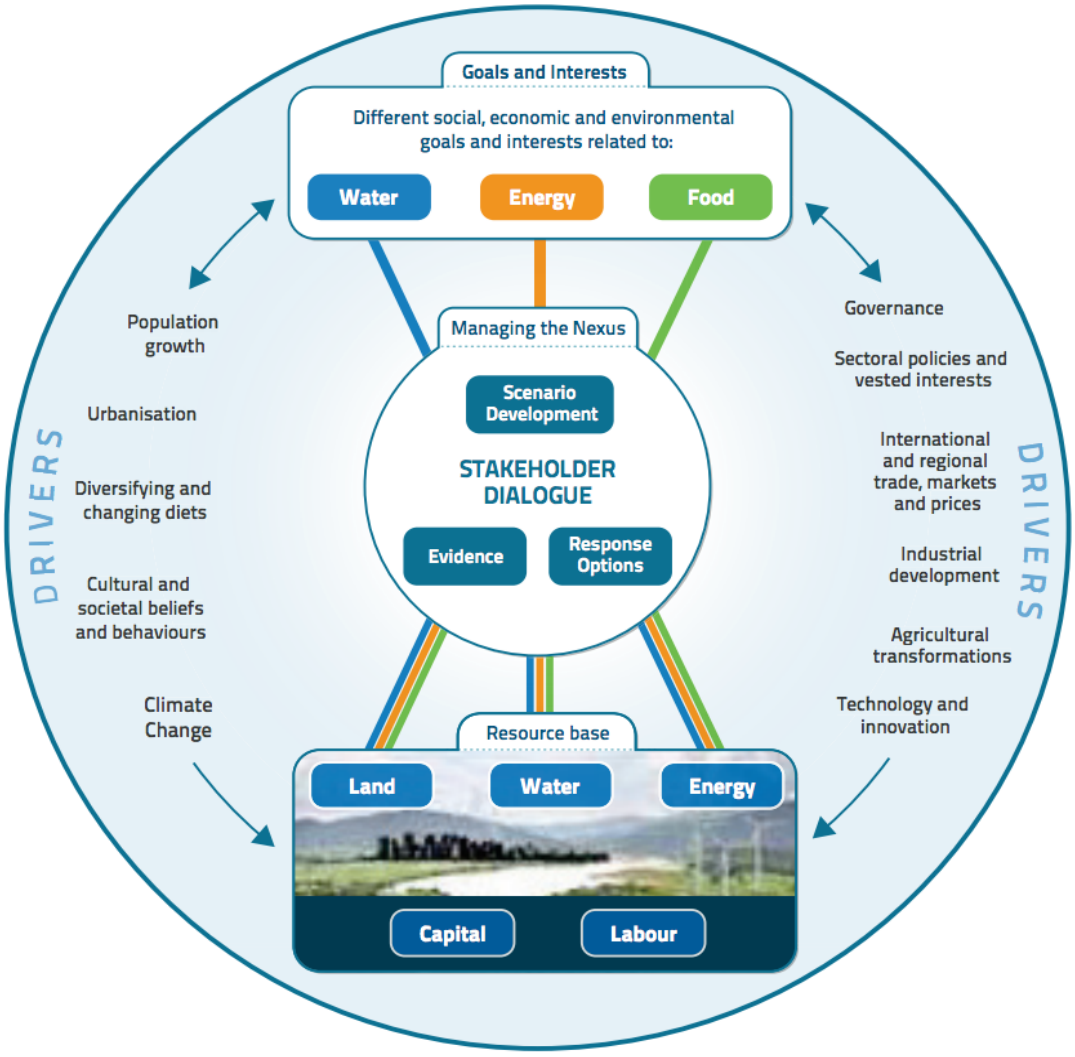
With the aim of providing an academic context for this research work, a descriptive and critical approach has been carried out, centered around the research question: *Where, as a country, does Morocco stand today in terms of efficiency and sustainability of the WEF Nexus management and what is the scope for further improving efficiency and sustainability through improved public policies, investments, approaches and practices?.* This Thesis has reviewed recent initiatives built around the Nexus, analyzed the different challenges in achieving the boundary crossing advocated by the international Nexus agenda, always having FAO's approach as the reference point, as it explicitly addresses interactions and feedback between humans and natural systems[10].

FAO's approach pivots on the resource base, including both socio-economic and biophysical resources, upon which we depend to achieve environmental and social justice. Interactions take place within the context of external global drivers, such as

[9] Werrell and Femia, "The Nexus of Climate Change, State Fragility and Migration," Angle Journal (Imperial College London), November 26, 2015.
[10] Food and Agriculture Organisation of the United Nations (FAO). Walking the Nexus Talk. Rome, Italy, 2014; p. 13.

demographic change, international and regional trade urbanization, industrial development, markets and prices, agricultural modernization, technological advancements and climate change as well as more site-specific internal drivers, like governance structures and processes, vested interests, cultural and societal beliefs and behaviors. Figure 2 illustrates the approach to the Water-Energy-Food Nexus that will be taken as theoretical base for the purpose of this research (FAO, 2014).

Figure 2. Interdependencies and external drivers of the WEF Nexus



Source: FAO, 2014.

Traditional research approaches, rarely address questions arising from the intersection of different dimensions -ignoring that decisions taken in a given dimension might basically affect the availability in the other Nexus dimensions. For such studies, integrated models are needed to investigate the intensity of the interdependency between various Nexus variables as well as other related externalities such as economic growth, poverty, biodiversity, sustainable

development, climate change or global security. Most of the tools being applied nowadays, are limited to individual sectors and therefore do not capture such complex interlinkages.

It is clear from the literature review that many attempts to address the WEF Nexus precede the recent integration of the Nexus into the international agenda. However, they have confronted several barriers namely related to cross-disciplinary collaboration, political complexity and current institutional silos[11]. It is unlikely that sectorial boundaries align with the established management units (Perrone *et al*. 2011). Such misalignment between management units and cross-sectorial activities presents extra difficulties in obtaining information on the Nexus interlinks.

The main contribution of the WEF Nexus is the acknowledgement of the coupled nature of water, energy, and food (Hoff 2011, Ringler et al. 2013, Allan et al. 2015). Advocating for synergies and minimizing trade-offs -regarding monetary and non-monetary gains and losses- among water energy and food is a critical aspect of sustainability (Biggs et al. 2015, Halbe et al. 2015) and should be aligned with the Sustainable Development Goals. Natural resources are finite, and human needs for them should be placed against the context of the limitations of these resources.

As a matter of fact, all these ambitious aspirations of the WEF Nexus -specifically the aim to capture various interdependencies across sectors and scales- could potentially become its downfall. Nonetheless, greater acknowledgement of interdependencies among state and non-state actors, more elaborated modeling systems to evaluate and measure WEF Nexus linkages for an improved management, might create enough momentum to overcome historical barriers and set up Nexus-sensitive approaches as a response to environmental challenges (H. Leck et al. 2015). In helping to move from theory to practice in the WEF Nexus, this research work sheds light on the implementation of what has yet mostly been an academic exercise.

1.3 Thesis structure

1.3.1 Thesis objectives and outline

The aim of this Thesis is to elucidate how to better address, assess and manage the WEF Nexus in a given context and to inform Nexus-related actions in terms of policies, strategies, and institutional set-up. This PhD is centered around the following research question: *Where, as a country, does Morocco stand today in terms of efficiency and sustainability of the WEF Nexus management and what is the scope for further improving efficiency and sustainability through improved public policies, investments, approaches and practices?*.

[11] Leck, H.,Conway, D., Bradshaw, M. and Rees, J. Tracing the Water-Energy-Food Nexus: Description, Theory and Practice. Geography Compass 9/8 2015, 445-460

The overall objective of this research work is to support countries and decision makers in identifying best practices and streamlining policies in the water, energy and agri-food management.

This research is divided in two main sections; the first one contains an assessment of the interlinkages and interdependencies among the three resources; while the second one suggests recommendations and particular policy proposals to improve the WEF Nexus management in Morocco were the case-study of this research is centered. Critical areas for action have been identified and guidance is provided for the implementation of a country-wide[12] WEF strategy, together with national policy recommendations.

This PhD intends to support filling some knowledge gaps by focusing on examining the Nexus latest trends and opportunities, vulnerabilities as well as consequences for the particular case of Morocco; as an option for climate change mitigation and adaptation.

1.3.2 Methodology applied

For the stocktaking section within the first part of this Thesis, a thorough literature review was conducted, paying special attention on natural resources availability to ensure the preservation of ecosystems.

In exploring the use of contemporary approaches and technologies in addressing the WEF Nexus, a comprehensive search of the latest scientific articles was conducted providing an overview of the state-of-the-art and latest trends. It is followed by a thorough identification and quantification of key Nexus interlinkages, highlighting the vulnerabilities that ought to be addressed.

The second part of this research, which is based on a case-study approach, employs two types of data:

- Qualitative data: Qualitative methods are used to describe measure and manage the Nexus in Morocco, the region of interest. This includes primary research methods such as Expert Interviews with key experts both at the national and international level, as well as sector-specific questionnaires. The qualitative analysis starts by examining where does Morocco stand in terms of the WEF Nexus management, analyzing its sustainability, efficiency and room for improvement. This step will take into account two significant features of the country in respect of WEF management: the resource diversity of Morocco - from high mountains to dry desert areas; so that a wide range of situations is examined; and the fact that North African countries, and particularly Morocco,

[12] Bearing in mind that the scale aspect is one of the most critical issues when designing WEF Nexus interventions, for the purpose of this Thesis, the country level has been the geographical scale chosen (as data availability was a conditioning factor for a sound analysis). However, it should be noted that in the existing literature, it remains unclear which is the most optimal scale.

are generally relatively advanced when it comes to the WEF management, compared to other regions such as its neighbors from sub-Saharan Africa.

- Quantitative data: Quantitative methods and platforms from existing International Organizations and Academia have been used, including the interactive Pardee Rand Food-Energy-Water Index[13], which enables the measurement of the WEF Nexus under future scenarios. For the purpose of this Thesis, fresh analysis on this quantitative data has been performed. Moreover, recognizing the difficulties of accessing some data, the quantitative analysis relies on the use of different international databases, such as the World Bank Climate Knowledge Portal[14], whilst encouraging national stakeholders to improve data collection and dissemination.

The policy analysis and recommendations stem from applied research as well as methodological development, being the ultimate goal of this research project to inform Nexus-related response options for Morocco, with the focus on policy recommendations, investments, strategies and best practices that are necessary to ensure a sustainable WEF management to tackle the effects of climate change in the country.

1.3.3 Overall results

All in all, this Thesis makes a contribution to the field by presenting various perspectives on the complex, multidimensional relationship between water, energy and food. The principal original scientific contributions from this PhD comprise: an identification of the nexus latest trends and technology solutions based on the available literature and expert knowledge; an analysis of the main challenges and opportunities the WEF nexus is facing; a deep look into to WEF Nexus trade-offs, contributions and impacts in Morocco as well as a country-level policy review, highlighting the existing Nexus approaches; which are comprehensively covered in Chapters 2 to 5.

The ultimate objective of this research is to provide relevant insights for decision-makers and guide the development of appropriate tools and policies to manage the WEF Nexus in Morocco. For that, recommendations are proposed under Chapter 6, putting the emphasis on:

- Increasing the efficiency of water use, together with the development of a comprehensive regulation of groundwater in order to optimize the use of such a scarce and critical resource in Morocco.
- Enhancement of renewable energy investment promotion to continue diversifying the country's energy mix, and therefore increasing its energy security by reducing the country's dependence on energy imports.
- The operationalization of the existing energy efficiency regulations, which entail a high potential for climate change mitigation.

[13] See: https://www.prgs.edu/pardee-initiative/food-energy-water.html
[14] See: https://climateknowledgeportal.worldbank.org/

- Development of measures to address and adapt to climate variability and maintain the agricultural productivity, for instance through climate resilient crops.
- Deployment of climate smart solutions throughout the country, in cooperation with the private sector.
- Finally, the need to accelerate and support R&D on Nexus-related technologies and solutions.

The conclusions of this Thesis argue that, by improving the governance on the WEF Nexus management, higher levels of security, stability and resilience could be achieved in Morocco. However, in order to trigger all the Nexus potential, the recommendations presented under Chapter 6, would need to be introduced into the national policies as a cross-cutting issue along with poverty reduction and climate change, to name a few.

Whilst this dissertation covers a number of aspects related to the water, energy and food Nexus; under Chapter 7, a number of areas are recommended where further work could be undertaken as a natural follow up to this research:
- It highlights the critical need of improving the information base in order to manage and develop Nexus-related interventions with sound statistical data sets.
- The importance of including the gender dimension in analyzing the Nexus.
- Further exploration on the most optimal scale of application.
- The study of the WEF Nexus as a source for income generation.
- The instrumental value of having an inventory of past experiences and lessons learnt to build upon in future interventions.

The overall conclusion of this PhD Thesis is that the WEF Nexus is a catalyzing force for social and economic development; such as poverty reduction, environmental sustainability, the creation of quality jobs, open borders to climate migrants, gaining respect for the rights of indigenous lands, women empowerment, rural development, political change, among many others.

Chapter 2: Breaking down the Nexus

2.1 Resource Dimensions

2.1.1 Water

Water security is the ability to access sufficient quantities of clean water to maintain adequate standards of food and goods production, proper sanitation and sustainable health care. In more detail, the key aspects of water security are[15]:

- Access to safe and sufficient drinking water at an affordable cost;
- Protection of livelihoods, human rights, and cultural and recreational values;
- Preservation and protection of ecosystems in water allocation and systems management;
- Water supplies for socio-economic development and activities;
- Collection and treatment of used water to protect human life and the environment from pollution;
- Collaborative approaches to transboundary water resources management within and between countries;
- The ability to cope with uncertainties and risks of water-related hazards.

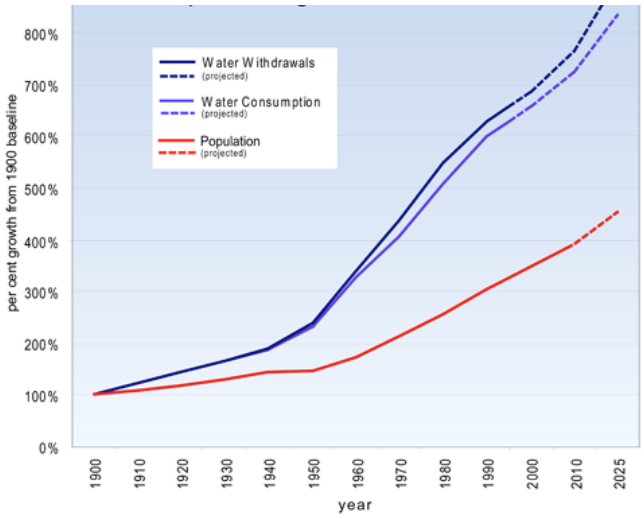
Major challenges facing water

As population increases in urban areas, so does the demand on water resources, and therefore water scarcity is expected to be even more aggravated in the coming years[16]. Moreover, indirect water demands are also expected to increase due to greater energy needs[17] -since most energy technologies are water intensive.

Figure 3 represents the world's increases in water withdrawals, water consumption and population growth since to 1900, and it also plots the projected growth of the curves until the 2025 horizon. It can be appreciated that the global use of freshwater has been growing at almost twice the rate of global population for the past century. It is also noteworthy to mention that from the total water volume worldwide, only a tiny fraction (0,79%)[18] represents unfrozen freshwater (not bound up in ice sheets or glaciers), which is mostly stored as groundwater and is arbitrarily distributed, not to say unfairly, around the world.

[15] GIZ, WEF Nexus Handbook, 2018
[16] See: http://www.fao.org/3/a-i7754e.pdf
[17] See: https://www.who.int/news-room/fact-sheets/detail/drinking-water
[18] See: https://na.unep.net/api/geas/articles/getArticleHtmlWithArticleIDScript.php?article_id=76

Figure 3 Global Freshwater Withdrawal, Water Consumption and Global Population, % growth since 1900 [19]



In addition, physical and economic constraints make it impractical and commercially unviable to move great volumes of water from areas of surplus to areas in need. Thus, regional scarcity has become a serious and exponential problem, given that population growth relies on regional water supplies which are being depleted, degraded and divided among more people[20].

Source: Shikomanov 1999 & US Census Bureau 2011 & Nurul Hassan 2016.

Looking at the future, global water demand is expected to increase significantly in the coming decades, especially for domestic, industrial and energy production purposes.

Low-income communities, who are already the most vulnerable to water supply are likely to be worst affected by climate variability. Thus, investments that increase coping capacities are crucial in order to reduce the risk of potential disasters to take place. Securing access to sustainable water and sanitation services is a critical sustainable development and climate change mitigation strategy for the years to come.

Opportunities

It is not that there exists a worldwide water shortage per se, however regions and countries still need to rapidly tackle the challenges deriving from water stress. Water ought to be treated as the limited and scarce resource it is, and careful attention should be paid on its demand management. An integrated water management approach can help aligning demand and supply patterns[21]. This entails conserving and valuing water, protecting and restoring freshwater and wetland ecosystems, investing in water infrastructure and technology and contributing to address climate change.

[19] The rate of growth in freshwater withdrawal and consumption has been even more rapid than global population growth.
[20] Gleick P, and Palaniappan M. (2010) Peak water limits to freshwater withdrawal and use. Proc Natl Acad Sci. USA.
[21] See: https://www.unwater.org/water-facts/scarcity/

The Water Cycle and Climate Change

The supply of water is directly affected by weather and climate. Besides water inputs from precipitation, evapotranspiration also causes considerable amounts of water losses and should therefore be taken into consideration. In addition, high temperatures and low levels of humidity can remove water from the land surface. Similarly, water demand is expected to change under the effects of climate change, especially with regards to population growth and economic development. Such changes tend to multiply the risks and operational challenges in the water sector[22].

Climate change is strongly related to the water cycle because as air temperatures rise, more water evaporates into the air and soils dry out. More water vapor can be held in warmer air, which might result in severe rainstorms and even extreme flooding in coastal areas. On the contrary, it can also result in extreme droughts, because when it rains, most of the water ends up to the rivers and therefore, the soil remains dry. Which results in more evaporation from the soil, leading to an increased risk of extreme drought.

Table 1. Water Security Facts and Figures

WATER SECURITY – Facts and Figures
○ About 4 billion people (≈2/3 of the world population), experience **severe water scarcity** during at least one month of the year (Mekonnen and Hoekstra, 2016).
○ 1.2 billion people (≈1/5 of the world's population) live in areas affected by **physical water scarcity** (where countries lack the necessary infrastructure to take water from rivers and aquifers), facing water shortage (UN, 2018).
○ 1.6 billion people (≈1/4 of the world's population) live in areas affected by **economic water scarcity** (UN, 2018).
○ 884 million people **lack access to clean water[23].**
○ 700 million **people worldwide could be displaced -Climate Migrants,** by intense water scarcity by 2030 (Global Water Institute, 2013).
○ 1/3 of the world's biggest groundwater systems are already in distress (Richey et al., 2015).
○ Poor quality water in Middle East and North Africa costs from 0.5% to 2.5% of GDP [24].

Source: own compilation of data.

[22] Information from this paragraph is largely drawn from the Climate Knowledge Portal of the World Bank. https://climateknowledgeportal.worldbank.org/country/morocco/
[23] See: https://www.unwater.org/water-facts/scarcity/
[24] See: https://www.unwater.org/water-facts/scarcity/

2.1.2 Energy

Energy Security is the uninterrupted availability of energy sources at an affordable price (IEA, 2019), ideally from a green and sustainable source.

Major challenges facing Energy

The contemporary challenge humanity is facing with regards to energy is filling the gap between demand and supply; with sustainable, reliable and inexpensive energy forms. While new energy sources are slowly changing the global scenery, fossil fuels continue to power most of our countries' needs.
Natural gas has erupted as an effective transitioning solution, since it pollutes less than coal -and other fossil fuels- per amount of energy produced, and it is also easier to transport over long distances. Most likely, meeting the energy needs of the future will require not just one alternative but all of them, shoulder to shoulder with traditional fossil fuels. Encouraging the growth of alternative energy sources go along with other energy related challenges such as the development and adoption of new sustainable transportation technologies, reducing the environmental impact and increasing energy efficiency, to name a few. However, despite extraordinary advances in technology, rapid economic growth in countries like China and India will inevitably increase the overall energy demand[25].

Opportunities

The renewable energy industry is rapidly evolving, for instance, there has been a rapid market decline in the cost of renewable energy technologies and real opportunities exist to significantly scale up a global energy transformation.
In addition, many parts of the world still face power supply deficits and are eager to leapfrog to renewables as an alternative to fossil fuels, in order to ensure energy security.

Energy and Climate Change

The energy sector is linked to climate variability and climate change in numerous ways: the production of energy is one of the main causes of climate change due to GHG emissions; and it is also affected by climate variability through changes in energy demand (population increase) and supply (operations disruption). The consequences are multiple; still they are both positive and negative[26].

[25] See: http://energy4me.org/all-about-energy/energy-challenges/
[26] See: Information of this paragraph is largely drawn from the Climate Knowledge Portal of the World Bank. https://climateknowledgeportal.worldbank.org/country/morocco/

Responsible for around 60% of greenhouse gases, energy is the principal contributor to climate change[27]. Strong fossil fuel dependence, together with the low efficient and out of date coal plants, are some of the reasons for the high contribution of the energy sector to global GHG emissions. This not only increases global temperatures but severely impact air quality and human health[28]. The role of renewable energy solutions in mitigating climate change is well proven. Therefore, shifting to renewable energy entails remarkable advancements on tackling climate change, as well as on achieving the Sustainable Development Goals (SDGs).

Table 2. Energy Security Facts and Figures

ENERGY SECURITY – Facts and Figures [29]

- 1/7 people still **lacks electricity**, and most of them live in rural areas of the developing world.
- Energy is the **main contributor to climate change**; producing around 60% of greenhouse gases.
- More efficient energy standards could reduce building and industry **electricity consumption** by 14 %.
- More than 40% of the world's population —3 billion people— relies on polluting and unhealthy fuels for cooking.
- As of 2015, more than 20% of power was generated through renewable sources.
- The renewable energy sector employed a record 10.3 million people in 2017.

Source: own compilation of data.

2.1.3 Food

Food Security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life (FAO, 2019). *Household Food Security* is the application of this concept to the family level, with individuals within households as the focus of concern.

[27] See: https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-7-affordable-and-clean-energy.html
[28] See: https://www.undp.org/content/undp/en/home/2030-agenda-for-sustainable-development/planet/sustainable-energy/renewable-energy.html
[29] See: https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-7-affordable-and-clean-energy.html

Major challenges facing Food

There is a growing stress on food demand since the world population is expected to grow by 50% and reach 9 billion by 2050. And it goes beyond ensuring the production of enough food to feed the world population, but to ensure everyone has access to the food they need for a healthy and active life. In doing so, it will be instrumental to ensure developing countries have a fair chance of competing in all commodity markets and that policies supporting agriculture do not unfairly distort international trade.
Yet, another big challenge is to put in place more effective systems for food security governance at all the levels: national, regional and international in order to ensure that farmers in both developed and developing countries earn similar incomes to those workers from the secondary and tertiary sector, in their respective countries. There is also the pressing need to ensure farmers' access to modern technologies and techniques to boost food production and productivity in the developing world, particularly in low-income and food-deficit countries (FAO 2009).

Opportunities

Sustainable farming techniques could positively impact developing countries food systems while supporting economic development and protecting the environment. Transitioning economies are the most affected by food scarcity. These new techniques can have a broad range of benefits, besides the predictable ones: a study published in the American Chemical Society's journal *Environmental Science & Technology* found that sustainable farming practices could increase yields in these nations by around 80% in just four years. Harvests of some crops even improved by 100%[30]. Achieving food security dramatically improves the well-being of people and triggers a number of additional benefits.

Food and Climate Change

Climate Change is undeniably already impacting -and will increasingly do so- the four dimensions of food security: food availability, food accessibility, food utilization and food systems stability (FAO 2008).
"Agriculture based livelihood systems that are already vulnerable to food insecurity face immediate risk of increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material, and loos of livestock. People living on the coasts, floodplains, mountains, dry lands and the Artic are most at risk. From this, an important conclusion can be drawn: people who are already vulnerable and

[30] See: https://www.sciencedaily.com/releases/2006/01/060123163315.htm

food insecure are the first and worst impacted by climate change, as they depend on vulnerable livelihoods mainly dependent on agriculture, in vulnerable areas" (FAO, 2016[31].

It is noteworthy that agriculture, fisheries and forestry besides suffering the effects of climate change they are also net contributors to it through the release of GHG emissions. While being part of the problem, they also entail part of the solution. By changing their practices, they can modify and reduce its impact.

Environmental change is upgrading the dangers, acting like a risk multiplier, especially with respect to the accessibility of water in warm conditions. In numerous spots, climate change is communicating through higher levels of dryness when dry, and of wetness when wet.

Table 3. Food Security Facts and Figures

FOOD SECURITY – Facts and Figures [32]

- There is a risk that **925 million people will go hungry** and around **1 billion people suffer from 'hidden hunger'** (UNICEF, 2010). The majority of the world's hungry people live in developing countries, where 12.9% of the population is undernourished.
- Food demand is expected to increase by 60% in 2050 based on 2007 levels (WHO, 2017).
- **Agriculture is the single largest employer in the world**, providing livelihoods for 40% of today's global population. It is the largest source of income and jobs for poor rural households.
- **Sub-Saharan Africa** remains the region with the **highest prevalence of hunger**, with the rate increasing from 20.7% in 2014 to 23.2% in 2017.
- 500 million small farms worldwide, most still rain fed, provide up to 80% of food consumed in a large part of the developing world. Therefore, investing in smallholder women and men is an important way **to increase food security and nutrition for the poorest**, as well as food production for local and global markets.
- If **women farmers** had the same access to resources as men, the number of hungry in the world could be reduced by up to 150 million.

Source: own compilation of data.

[31] See: https://www.uncclearn.org/sites/default/files/inventory/a-i5188e.pdf
[32] See: https://www.un.org/sustainabledevelopment/hunger/

2.2 Interconnections and Interdependencies

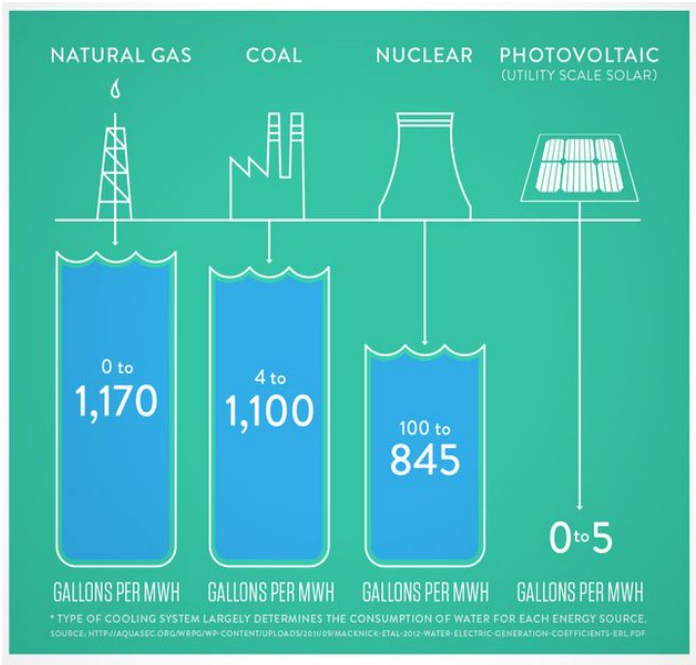
In this section, the relationships, synergies and trade-offs among the components of the Nexus, are addressed.

2.2.1 Water-Energy

Most energy systems, including new energy technologies, are water-intensive and it is well known to be a potential future limitation in ensuring energy security. Water is essential for cooling power plants, for electricity generation and for the production of biofuels, also for the extraction, mining, processing, refining and disposal of fossil-fuel residues.

Given that our energy and water systems are highly interdependent, there is a growing demand for energy to alleviate water scarcity pressures. Renewable energy seems to offer a clear path forward: fewer greenhouse gas emissions and less wasted water resources. Ensuring a good governance of water and energy is crucial in safely managing these two finite resources.

Figure 4. Water Consumption for Operational Use by Energy Type



Source: JBS New, The Solar Power[33].

On the other side, wind energy, photovoltaic, solar thermal, natural gas, crude oil… every type of energy requires water to generate power -even if it is a minimal amount for manufacturing and site development- as shown in Figure 4. So, it is not surprising that a considerable percentage of a country's electricity is consumed by the water sector for pumping water, in water treatment processes or for desalination applications, among others.

[33] See: https://jbsnews.com/2014/07/11/the-solar-power-water-nexus/

2.2.2 Energy-Food

The agriculture and food sectors can be important electricity consumers, accounting for approximately 30% of the global national energy consumption on average. This value can even be higher at the neighborhood or provincial levels; whilst other times the farming sector might be small and unproductive, with little demand. In such cases, the most optimal solution are off-grid energy sources, in order to avoid the high costs derived from grid connection -which tend to be rather high for small grids. Therefore, it is vitally important to consider electrification plans and energy conditions at local, regional and national level, as this offers possibilities to rethink the optimal system design.

2.2.3 Food-Water

Agriculture is profoundly reliant on water usage, and is directly affected by water risks. In addition, it is the largest user and polluter of water. So, in having a productive and sustainable agri-food sector, an optimized water management will prove to be crucial (OECD, 2020).
Agriculture accounts on average, for 70% of all water withdrawals globally. Moreover, "irrigated agriculture represents 20% of the world's cultivated land, and contributes to 40% of the total food production. Given that irrigated agriculture is, on average, at least twice as productive per unit of land, provides an important buffer against increasing climate variability, and allows for more secure crop diversification, it is certain that irrigation will continue to play a key role in ensuring global food and nutrition security" (World Bank, 2020).

2.3 WEF Nexus: A Global Challenge

2.3.1 Good Governance and the Nexus

The international community is well aware of the challenges of water, energy and food, but has so far addressed them in silos, within sectorial limits. The Water-Energy-Food Nexus is at the forefront of the global agenda, responding to the need of addressing it from a holistic point of view.
At the nation level, the lack of appropriate coordination, divided sectorial obligations, and irregularities among regulations and administrative systems may prompt skewed motivators (World Water Development Report 2014 & UN Water 2017). In achieving a satisfactory WEF Nexus management, decision-makers, including those in charge of only one of the three sectors, need to consider more extensive impacts and cross-sectorial effects. Appropriate sectorial management

with a Nexus approach, cross-sectoral coordination and enhanced dialogue, are needed to ensure that trade-offs and co-benefits are taken into account. Supporting this development is a requisite to evaluate future policy options within the context of a changing world.

2.3.2 SDGs and the Nexus

In 2016, all countries of the world adopted 17 ambitious policy objectives: the Sustainable development Goals (SDGs) to end poverty, protect the planet, promote gender equality, end hunger and ensure prosperity, as part of the United Nations 2030 Agenda. The SDGs represent targeted areas of action at the global level in order to reach "the future we want". In particular, SDG 2, SDG 6 and SDG 7, directly address the demand for improving water, energy and food security respectively, as shown in Table 4 and Figure 5 below:

Table 4. SDGs and the Nexus.

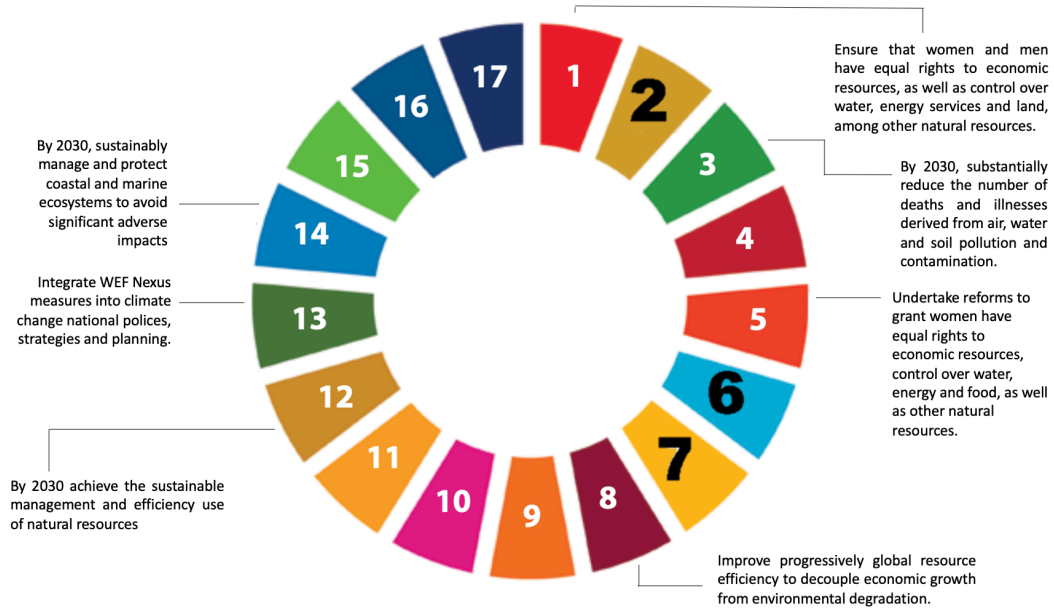
SDG 6 – Clean Water and Sanitation is defined in the Sustainable Development Goals as 'access to safe drinking water and sanitation', both of which became a human right in 2013. This means the provisioning, treatment and management of water for human use (in support of water security). More recent water security definitions emphasize the availability of and access to water for all human and ecosystem uses, which is also important from a Nexus perspective (e.g. Grey & Sadoff 2007).
SDG 7 – Affordable and Clean Energy aims to ensure access to affordable, reliable, sustainable and modern energy for all by the end of the next decade. From expanding access to electricity, to improving clean cooking fuels, from reducing wasteful energy subsidies to curbing deadly air pollution that each year prematurely kills millions of people around the world. The adoption of an energy specific sustainable development goal was a milestone in moving the world towards a more sustainable and equitable system. But there is an urgent need for action on all fronts, especially on renewables and energy efficiency, which are key for delivering on all three targets – energy access, climate mitigation and lower air pollution.
SDG 2 – Zero Hunger targets 2030 to end hunger and all forms of malnutrition. This is to be accomplished by doubling agricultural productivity and incomes of small-scale food producers, especially women and indigenous people, by ensuring sustainable food production systems, and by progressively improving land and soil quality.

Source: own creation.

Although these three SDGs highlighted directly address the WEF Nexus security, the remaining 14 SDGs are also linked in a one way or another to improving water, energy and food management. Thus water, energy and food are prevailing development concerns. Some examples of this have been (non-exhaustively) highlighted in Figure 5.

Looking at the following graphic, it is easily apparent how supporting a WEF Nexus approach will have ripple effects that support each sustainable development goal (Liu et al., 2018).

Figure 5. The 17 SDGs and their linkages to the WEF Nexus



Source: own creation building upon the SDG's pie chart of the United Nations.

The WEF Nexus is an approach to development which attempts to integrate goals across sectors in order to prevent advancement in one sector from affecting others, and it therefore inherently supports the SDGs set up.

2.3.3 Climate Change and the Nexus

The impact of climate change on the WEF Nexus is significant and should be considered and acted upon to continue to make progress. Climate change-associated weather events, such as flooding and droughts, have emerged as the biggest challenges faced by fast-growing and emerging economies (Swain, 2011). Temperature is expected to continue rising and rainfall is expected to continue changing its patterns, increasing uncertainty and risk.

The dominant development pattern is underpinned by sectors that are highly exposed to climate variability and change, especially agriculture, water infrastructure, and hydropower. However, sectorial approaches have been referred to as a hindrance to sustainable development and efficient resource utilization. Given that most resources tend to be interconnected in nature and face interlinked challenges, there should be a development approach from a cross-sectorial perspective. To this end, cross-discipline approaches like the WEF Nexus prove to be useful in tackling climate change.

Chapter 3: Challenges and Opportunities

3.1 Challenges

Despite the ideological prominence and awareness of the water, energy and food Nexus, it is not always effectively managed. There are many challenges facing the WEF governance, especially when it comes to its implementation, due to different political boundaries, a lack of a clear policy framework, and the high cost of its technological implementation.

3.1.1 Governance and Data Availability

One of the most prevalent challenges facing WEF governance is different sovereignties. It is difficult to establish a global WEF plan, communicating and implementing it transversally within a country. A Nexus approach often cannot be implemented because of the existing sectorial governance system," (McNamara et al. 128, 2018). In other words, the denomination and sectioning of governments can make it difficult and often impossible to drive change with a global impact. A continuing recognition and advocacy for WEF innovations will be paramount to its success.

In addition, it is a challenge to establish a clear policy framework for WEF governance. In order to have a compelling argument to incentivize nations to adopt a WEF governance, there must be a clear framework and a clear communicable message of the Nexus and its importance. Additionally, these goals may be multi-faceted, meaning they need to apply to different sectors. By the same token, what may work for long-term sustainability on a national scale may not work on a local scale, especially rural ones. If a policy is not widely applicable, there is no incentive for states to adopt it, and no governing body can force them to do so. What brings us to another challenge, the best geographical scale to address the WEF Nexus. There is no clear answer in the scientific literature, and experts have contradictory opinions on it. What seems to be clear is that the National scale seems to be the most practical, as it is where most reliable, transparent and available data is, whilst at the local and regional levels that tends to be somewhat rare.

Governing the global WEF Nexus and maintaining its sustainability and health requires an abundance of available data and appropriate and consistent monitoring. The WEF governance further delineates the need for technological advancements, citing monitoring of "climate, hydrology, and topography as well as socioeconomic factors" (Ibid., 97). While it is worth noting that some institutions conduct regular research on socioeconomic factors, much of the work would fall on the WEF governance to conduct. In order to combat this problem, WEF monitoring would need to ensure global financial recognition and support in tandem with quick and efficient collection and data analytics technologies.

3.1.2 Poverty and Unequal Distribution of Resources

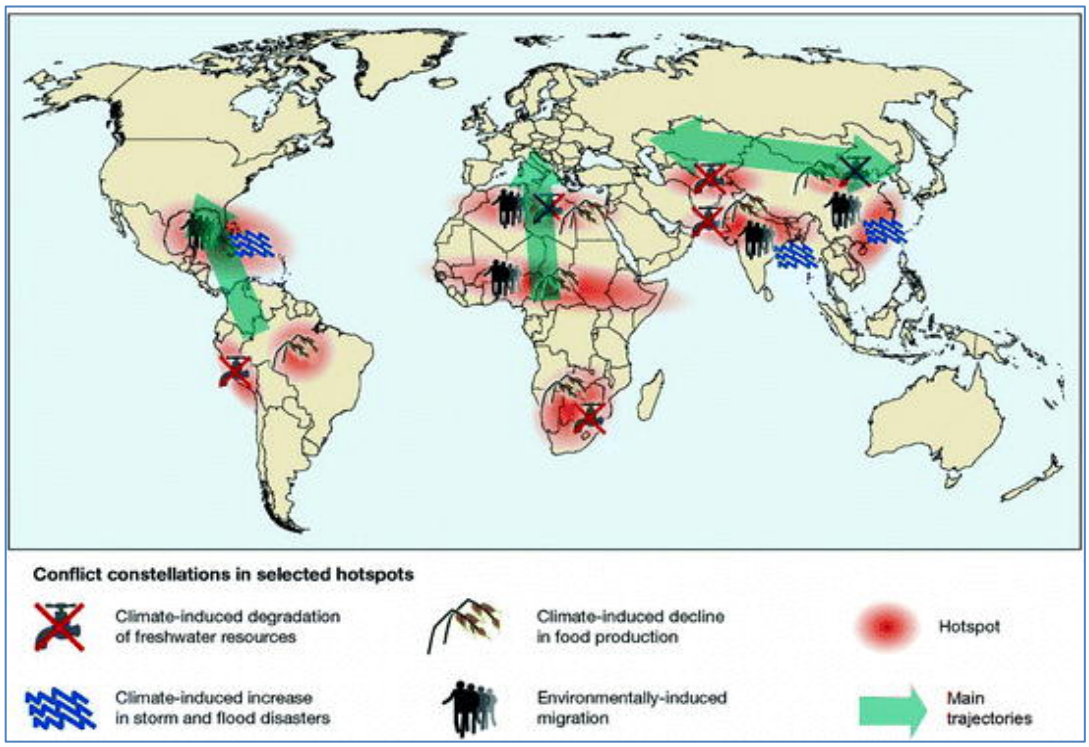
Another challenge that has been exploited by some critics of the WEF Nexus Governance is that the Nexus is concealing the larger issues that are happening. Critics are claiming that the WEF Nexus is taking the attention of world leaders away from the big picture: the inequality in the distribution of resources. The end goal of the WEF Nexus is for everyone to have access to sustainable resources, but currently, the problem of disproportionate distribution to less developed countries is contributing to the issues of social instability.

3.1.3 Resource Scarcity and Climate Migrants

Resource scarcity amid the water, energy and food Nexus has several consequences, one of which is forced migration. This forced migration can turn people into refugees, seeking shelter from the international community. In addition to resource scarcity, climate change-induced natural disasters cause forced migration as well. The Environmental Justice Foundation (EJF) estimates that extreme weather events, or climate-related disasters, displace 41 people per minute (Protecting climate refugees, 2017). According to a study conducted by Kolmannskog and Trebbi, "We can call them climate-related disasters since climate change can influence their frequency, severity, time, and location; storms, floods, and droughts all belong to this category" (Kolmannskog & Trebbi, 2010). Once unprecedented, these severe storms are becoming more and more common. In March of 2019, Tropical Storm Idai struck the southeast coast of Mozambique. This storm, the worst in the nation's history, internally displaced 146,000 people. In fact, "The U.N. High Commissioner for Refugees reported that 1.85 million people needed assistance" (Podesta, 2019). As storms of this caliber become everyday occurrences, the international community will be forced to respond to a multitude of new crises. In reality, their impacts are becoming more severe as "the number of recorded natural disasters has doubled from approximately 200 to over 400 per year over the past two decades" (Kolmannskog & Trebbi, 2010). Many issues will arise from increased frequency and intensity. Resource scarcity and extreme weather will force migration, especially in developing countries as shown in Figure 6 below. The Middle East and North Africa will most likely see increased competition within and between countries for resources, such as food and water. The extreme weather, resource scarcity, and subsequent migration will cause increased frequency and severity of disease; in addition, it will put stress on border control. According to John Podesta, the founder and director of the Center for American Progress, "All of these challenges are serious, but the scope and scale of human migration due to climate change will test the limits of national and global governance as well as international cooperation" (Podesta, 2019).

The EJF defines climate refugees as "persons or groups of persons who, for reasons of sudden or progressive climate-related change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes either temporarily or permanently, and who move either within their country or abroad" (Protecting Climate Refugees, 2017). Yet, the United Nations Migration Agency, IOM, points out that climate migrants have different characteristics, and therefore needs, than those fleeing social or political persecution or conflict. Defining climate migrants as refugees fails to address the complexities of climate-related migration. For one, climate migration is primarily internal, leaving people under the responsibility of their home state, not a third country or the international community. Another key difference is that migration is not necessarily forced. Resource depletion and changes in growth patterns can be slow to progress. The IOM suggests countries address migration management before refugee protection. Additionally, "Isolating environment/climatic reasons is difficult, in particular from humanitarian, political, social, conflict or economic ones. It can sometimes be an impossible task and may lead to long and unrealistic legal procedures" (Ionesco, 2019). The Head of Migration, Environment, and Climate Change for the IOM, Dina Ionesco, also worries that opening and changing the definition of a refugee in the 1951 Refugee Convention could weaken protections for refugees and decrease the international responsibility (Ionesco, 2019). The issue of addressing climate migration is complex and involves many agencies and legalities, as well as international cooperation. There is no simple answer to the issue, but the UNHCR has decided to take steps to protect those affected by climate change.

Figure 6. Climate Migration Routes



Source: Fernando N., Warner K., Birkmann J. (2010) Migration and Natural Hazards: Is Relocation a Secondary Disaster or an Opportunity for Vulnerability Reduction?. In: Afifi T., Jäger J. (eds) Environment, Forced Migration and Social Vulnerability. Springer, Berlin, Heidelberg.

The World Bank estimated in 2018 that 143 million more climate migrants will come out of Latin America, sub-Saharan Africa, and Southeast Asia by 2050 (Podesta, 2019). Currently, there is a gap in protection for most climate migrants, as they don't meet refugee status. Because most are internally displaced, they are protected by Guiding Principles on Internal Displacement, but not the 1951 Refugee Convention. Some conversations have taken place to address this issue.

Regardless of how we legally classify climate migrants, it is undeniable that people are being forced out of their homes and livelihood due to the effects of climate change.

3.2 Opportunities and Trends

3.2.1 Smart and Sustainable Cities

Today, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050 (UN, 2018). Projections show that urbanization, the rural exodus, together with population growth could add another 2.5 billion people to urban areas by 2050, with almost 90% of this expansion taking place in Asia and Africa, as indicated by the United Nations World Urbanization Prospect 2019[34]. While this migration to cities is commonly accepted, it can place stress on critical resources such as water, energy, and food as most large cities are congested with high-density populations. The WEF Nexus resources are all interrelated, which is why it is so important for urban areas to realize the critical role they play to help conserve and sustain such resources. This is one of the major challenges posed when managing the WEF Nexus.

To help combat this problem and save critical resources, urban areas around the world strive to become smart and sustainable cities. A smart city utilizes innovative information technologies to oversee various aspects of a city that can make it more efficient. A sustainable city works to combine environmental protection and quality of life for the population within it.

[34] The World Urbanization Prospects is published by the Population Division of the United Nations Department of Economic and Social Affairs (UN DESA). It has been issued regularly since 1988 with revised estimates and projections of the urban and rural populations for all countries of the world, and of their major urban agglomerations. See: https://population.un.org/wpp/

3.2.2 Attaining a circular economy model

A circular economy model is an economic system designed to eliminate waste by keeping resources in the loop at their highest utility and value. In such model, resources flow in a closed-loop system by using, remaking, recycling, making, and reusing of all materials.

Actions towards a circular economy model promote value-retention and environmental impact reduction while simultaneously reducing costs and creating economic opportunities, contributing to a cleaner production and a more resource efficient consumption. Circular Economy will prove to be instrumental in decoupling economic growth from resource depletion, thus alleviating the pressure on water, energy and food among other natural resources.

Policy and decision makers managing the WEF Nexus, should pay attention to new emerging business models and to best practices that embrace a circular economy and leapfrogging technologies that will drive sustainable development (UNEP Global Resources Outlook, 2019).

3.2.3 Including a gender perspective

Gender equality is instrumental in achieving a sustainable development, and consequently it is also key in addressing WEF Nexus security. However, the gender perspective is frequently neglected when applying the WEF Nexus approach.

The consideration of gender concerns in the WEF Nexus exhibit how the demand of work and time for women in agriculture, enterprises, and household facilitates access to water and energy, and in turn women's increased access to water and energy leads to their participation in production of food and manifestation of their agency. Such an analysis of the roles and contributions of women and men to the water, energy and food sectors helps in understanding the complex interrelationship between women food producers, with their large scale role in agriculture and collection of water and fuel, yet at the same time their exclusion from access to ownership and control rights to critical factors of production (Kelkar et al, 2017), and the requirement to include gender sensitivity in managing the WEF, namely in development transitions.

On a positive note, gender considerations are beginning to be systematically included in the WEF Nexus work of some organizations (CSIRO, 2017). There is huge potential to be untapped by empowering women to take action in managing the WEF Nexus.

3.3 Best national and regional practices

Several countries across the globe are making groundbreaking changes to their approaches towards food, water, and energy and their inherent synergistic impact to create a sustainable society. Additionally, some countries have also made pledges and goals with specific dates in which they will make improvements to their sustainable practices for the future.

- For instance, in 2008, Northern China implemented the North China Plain Water Conservation Project to improve their efficiency and sustainability in water usage. This project, affecting over 250.000 farms, funds improvements leading to more efficient drainage and irrigation in addition to water and soil conservation practices (Akiyama, 2017). While the central focus of this governance was to conserve water, it also impacts their food sustainability as water, energy, and food are all interconnected according to WEF Nexus theory. In improving water use in relation to agriculture, agricultural production was also made more efficient. Northern China proves an example of effective WEF practices due to their investment in institutional reform in irrigation and soil conservation, leading to more efficient water use without suffering compromise to their agricultural yield.

- In the same light as Northern China, Israel's main focus is water security. Located in the arid Middle East, water is a critical resource for the Israelis and will almost certainly remain a central focus for the country moving forward. To meet this situation head-on, Israel has made drastic reforms in the sector of water conservation. Specifically, approximately 50% of the nation's agricultural water supply will be recycled by 2022. In addition, they project 85% of their wastewater to be also recycled in the same time period. (Closas et al.) They also remain a world leader in desalination practices. These practices are a positive portrayal of the WEF nexus and positively affect both the sustainability of food and energy.

- In addition to water-centered policy, several policies that were originally food-focused have positively influenced the entire WEF Nexus for nations. France is the best example of positive food-focused policy. The French government has become the first nation to ban food waste for supermarkets (forcing them to donate their unused food to local charities), having a profound impact on both energy and water use. In regards to energy, the considerable reduction of food waste means less energy needs to be used to break down waste in landfills. Furthermore, according to economic theory, this will cause supermarkets to reduce their purchases in order to ensure their business remains profitable, which cuts the amount of energy and fossil fuel consumption needed to transport the large amounts of food that supermarkets bring in every day. Moreover, if supermarkets are purchasing less food, farmers will produce less,

cutting their amounts of irrigation needed to produce such a large number of crops. By decreasing the amount of irrigation needed to feed crops, France has been able to preserve precious energy and water resources.

- From a more energy-focused perspective regarding WEF policy, Norway is spearheading the practice of national energy sustainability. Norway's energy mix is one of the greenest in the world, with approximately half of its total energy coming from sustainable sources in 2015. The most used source of sustainable energy utilized by the Norwegians is hydropower. In fact, according to Nordic Energy, "Abundant hydropower has fostered energy-intensive industries and electric heating. It accounts for 96% of electricity generation and three-quarters of this are fully dispatchable" (Nordic Energy, 2018).

Again, the impacts of policy changes in just one element of the WEF Nexus can be seen across the nexus in its entirety. Fracking and other fossil fuel extraction techniques often require large amounts of water, thus the reduction of reliance on these practices can have a profound impact on the conservation and sustainable use of water. Additionally, the processing of food from its inception in irrigation to its final form in packaging and transportation relies on energy, and the greater the percentage of sustainable energy sources used in this process, the greater the food sustainability will be. In short, these countries are leading the way in the push for more sustainable practices, which have profound impacts on the global WEF nexus.

Many of WEF's current trends are positive in nature and demonstrate that the Nexus is evolving into an even more productive and beneficial model. While the WEF Nexus is not perfect and there is still room for improvement, it represents the best model for tackling water, energy, and food in today's sustainable world. For all of these reasons, WEF Nexus management should be a top priority not only nationally but internationally.

Chapter 4: Morocco Country Profile

4.1 General Information[35]

Figure 7. Map of Africa

Size[36]**:** 446.550 km2
Population: 36 M people
Population growth: 1,25% annual
Life expectancy (at birth): 76,5 years
Urban population: 62,45%
GDP per capita: 3.237,99US$
Poverty headcount ratio: 4.8% (<$1.90 a day)
Gini index: 39,50 (ranked the 63rd most unequal of 159 countries rated)
HDI: 0.676 (ranked 121st of 189 countries rated)
CO2 emissions: 1.751 metric tons per capita

Source: www.geographicguide.com

Morocco is a country modestly stable and prosperous compared to the regional standards, being the 5th largest economy in Africa. Morocco is a unitary constitutional monarchy with an elected parliament. It wields remarkable influence in both the Arab world and Africa, being considered a regional power and a middle power. Morocco is a member of the Arab League, the Union for the Mediterranean and the African Union.

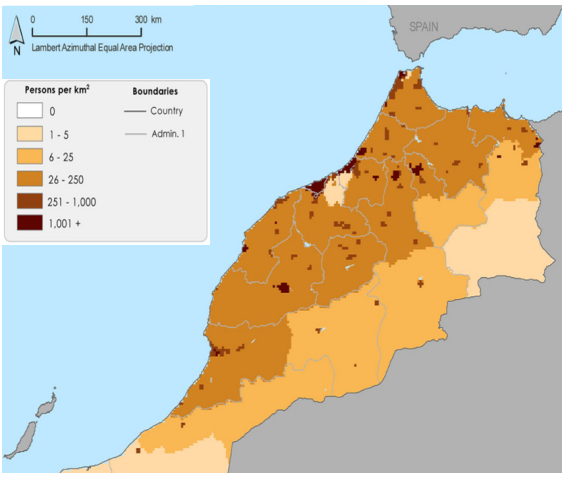
With regards to international environmental agreements, in 1995 Morocco ratified the United Nations Framework Convention on Climate Change (UNFCCC, 1992) and the Kyoto Protocol in 2002. Climate change is a priority for Morocco in its multilateral engagement; the government acted as a host of COP7 in 2001, where the Marrakech Agreement was reached, and the COP22 in 2016 in Marrakech, where the Paris Agreement was ratified. Lately, Morocco has acted as a powerful advocate for Africa at COP23 in Bonn and at the COP24 in Katowice[37].

[35] World Bank (n.d.), 'Morocco Country Database'. Available from: https://data.worldbank.org/country/morocco
[36] Figure adopted by the United Nations. However, this figure does not include the area of Western Sahara which accounts for additional 266,000 km2. This does not imply or mean any position against the legal or constitutional status of Western Sahara
[37] IEA 2019: 'Energy Policies beyond IEA Countries: Morocco 2019'. https://www.iea.org/countries/morocco

4.1.1 Geography

Morocco is located in the Maghreb region of North Africa. It faces the Mediterranean Sea to the north and the Atlantic Ocean to the west, with land border with Algeria to the east and Western Sahara to the south. It also counts with Spanish exclaves, namely: Ceuta, Melilla and Peñon de Vélez de la Gomera. Morocco's capital is Rabat and its largest city is Casablanca. The country spans an area of 446,550 km2 (figure adopted by the United Nations -it does not include the area of Western Sahara which accounts for additional 266,000 km2. This does not imply or mean any position against the legal or constitutional status of Western Sahara).

Figure 8. Morocco Population Density Map, 2000

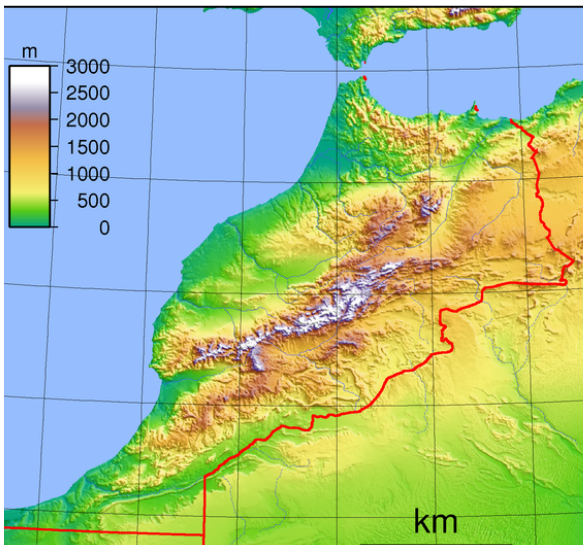


Source: https://www.maps-morocco.com

It counts with a population of over 36 million people. The majority of the population lives in the northern half of the country, predominantly along the coast, as shown in Figure 8. Most of the southeast is in the Sahara Desert and as such is generally sparsely populated and economically unproductive. The percentage of people living in urban areas continues to rise. In 1980, only 42% of the population lived in urban areas[38]. This number was 62% in 2018 and is projected to continue growing[39].

Besides Morocco's important maritime front, a large part of the country is mountainous, as it can be seen in Figure 9 below:

Figure 9. Topographic map of Morocco
Source: https://www.maps-morocco.com



- The Rif Mountains are located in the north, over the region bordering the Mediterranean from the northwest to the northeast.
- The Atlas Mountains are mainly located in the center and the south of the country, including the Middle Atlas, the High Atlas and the Anti-Atlas, which culminate at Toubkal with 4.165m.
- In addition, plains stretch along the entire coast of the country; they are narrow along the Mediterranean coast

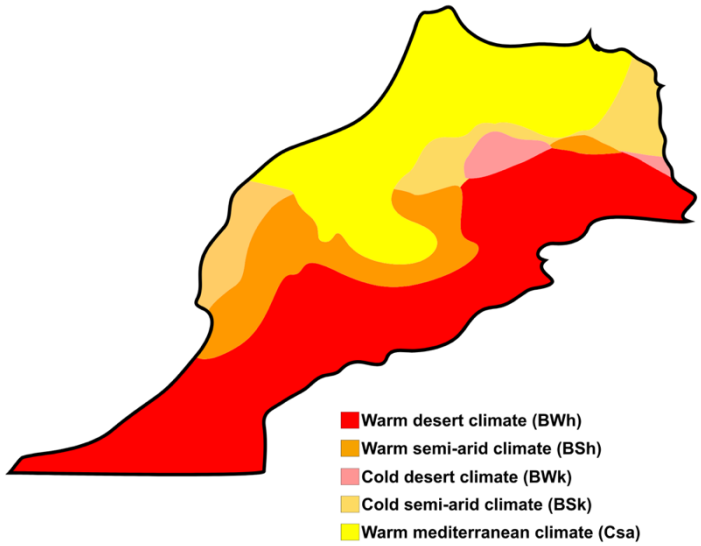
[38] World Bank (n.d.), 'Morocco Country Profile. Available from: https://data.worldbank.org/country/morocco
[39] HCP – Moroco's Statistics Office forecast, May 2017. https://www.hcp.ma/Population-du-Maroc-par-annee-civile-en-milliers-et-au-milieu-de-l-annee-par-milieu-de-residence-1960-2050_a677.html

and wide along the Atlantic. Finally, in the south of the country and in the southeast of the Atlas, there are desert to semi-desert plateaus and plains.

4.1.2 Climate

Overall Morocco has a Mediterranean climate with maritime, mountainous and Saharan influences, as shown below in Figure 10. It has a temperate climate with lush forests in the northern and central mountain ranges of the country, giving way to drier conditions and inland deserts further southeast, with an essentially semi-arid to arid climate. The coastal plains experience mild temperatures even in summer, due to the cold Canary Current effect in its Atlantic coast. In general, besides the southeast regions (pre-Saharan and desert areas), Morocco's climate and geography are very similar to the ones in the Iberian Peninsula.

Figure 10. Moroccan Climate pattern map



Source: https://upload.wikimedia.org/wikipedia/commons/d/db/Morocco_map_of_K%C3%B6ppen_climate_classification.svg

In the Rif, Middle and High Atlas Mountains, there exist different types of climates:

- Mediterranean along the coastal lowlands, giving way to a humid temperate climate at higher elevations with sufficient moisture to allow for the growth of different species of oaks, moss carpets, junipers and Atlantic fir which is a royal conifer tree endemic to Morocco. In the valleys, fertile soils and high precipitation allow for the growth of thick and lush forests. Cloud forests can be found in the west of the Rif Mountains and Middle Atlas Mountains. At higher elevations, the climate becomes alpine in character, and can sustain ski resorts.

- Dry weather. In the south-eastern part of the Atlas Mountains, close from the border with Algeria, the climate is very dry, with long hot summers. Whereas in the lowland regions in the east of the Atlas, extreme heat and low moisture levels are especially marked due to the rain shadow effect of the mountain

system. The southeastern-most portions of Morocco are very hot, and include portions of the Sahara Desert, where vast swathes of sand dunes and rocky plains are dotted with lush oases.

- Contrary to the Sahara region in the south, coastal plains are fertile in the central and northern regions of the country, and comprise the cornerstone of the agriculture in Morocco, on which 95% of the population depends on. The direct exposure to the North Atlantic Ocean, the proximity to mainland Europe and the long-stretched Rif and Atlas Mountains are the factors of the European-like climate in the country's northern half. That makes Morocco a country of contrasts.

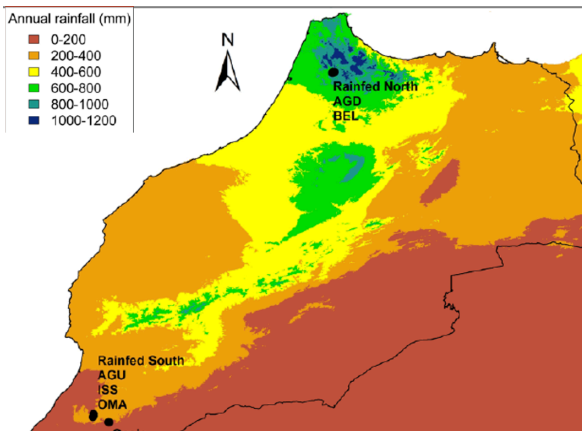
As pointed out by a World Bank study (2013), climate projections in Morocco indicate that climate change is expected to result in an increase of temperatures (up to 3.7°C by 2030) and a reduction in rainfall (by 5 to 15% by 2030 and 10 to 25% by 2050).

4.1.3 Precipitations and droughts

Annual rainfall in Morocco is different according to regions, as shown in Figure 11. In the north-west region of the country, between 500-1200 mm are received, while the north-east receive between 350-600 mm. North-central Morocco receives between 700-3.500 mm. The area from Casablanca to Essaouira, on the Atlantic coast, receives between 300-500 mm. The regions from Essaouira to Agadir receive between 250-400 mm. Marrakesh region in the central south receives only 250 mm a year. The southeastern regions, basically the driest areas, receive between 100-200 mm only, and consist basically of arid and desert lands.

Figure 11. Rainfall map of Morocco

Water resources are characterized by spatial and temporal scarcity and irregularity (ibid.). Next to population explosion and industrial growth, agricultural extension with more and more artificial irrigation is a reason for this stress on water resources (IUCN, 2014; World Bank, 2016d). Irrigation, however, is needed, as only 18.03% of the country's landmass is arable and can be used for agriculture (World Bank, 2016a).



*Source:*https://www.researchgate.net/figure/Rainfall-map-of-Morocco-with-sampling-locations-marked-See-Table-1-for-explanation-of_fig1_293026014

Droughts in Morocco are increasing in frequency and intensity (World Bank, 2017). Moreover, the country's average temperatures are rising as rainfall becomes more sporadic, both affecting the different parts of the country in an unequal way. Due to climate change, this trend is likely to be even more exacerbated in the coming

years. Drought damage to the agricultural sector affects both rural livelihoods and the national economy.

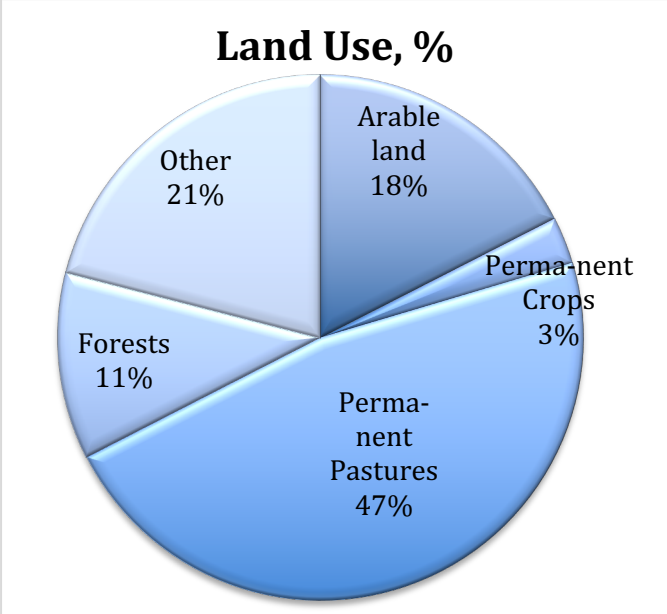
Long-term climate change is making Morocco, which already faces rural water scarcity, more vulnerable to extreme weather events. Increased climate variability leads to stronger droughts, which adversely affect livestock and rain-fed crops (World Bank, 2018).

4.1.4 Land and Environment

Botanically speaking, Morocco has a rich variety of vegetation, thanks to its diverse climate and rainfall patterns. From lush large forests of conifer and oak trees typical of the western Mediterranean countries; Morocco, Algeria, Italy, Spain, France and Portugal.

The main land-related challenges in Morocco are desertification and land degradation (soil erosion resulting from vegetation destruction, farming of marginal areas, overgrazing, etc.); as well as polluted water supplies by raw sewage; siltation of reservoirs; oil pollution of coastal waters[40]. Figure 12 below shows the share of land use per activity.

Figure 12. Morocco's land use, %



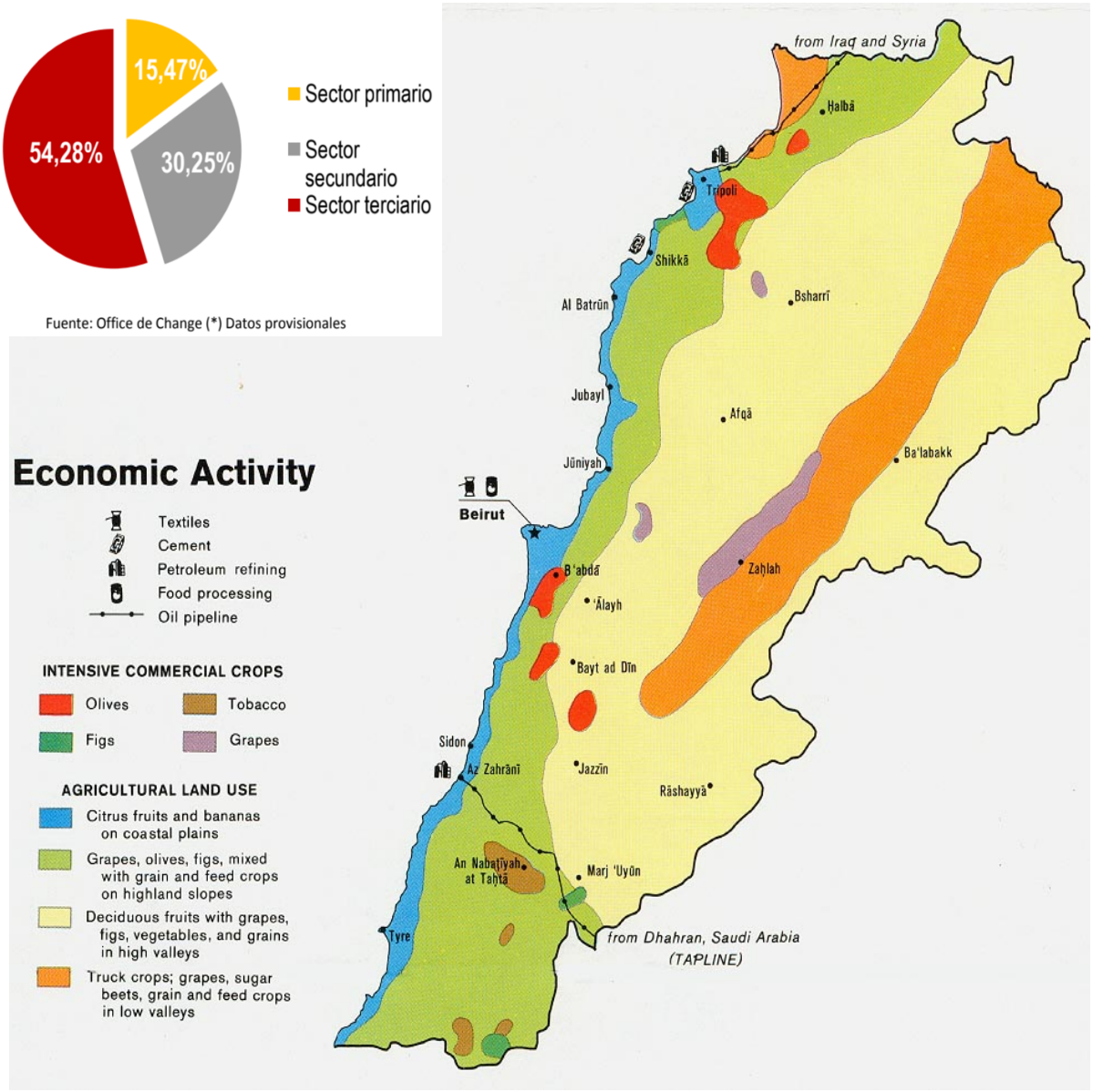
Source: Own compilation of data from The World Factbook, CIA 2011.

[40] CIA, The World Factbook, See: https://web.archive.org/web/20121014053842/https://www.cia.gov/library/publications/the-world-factbook/geos/mo.html

4.1.5 Productive Sectors

The map in Figure 13 below shows the main economic activities of Morocco and the areas with the highest economic interest. Morocco's forests cover 12% of the land, 18% are farmlands and 5% are for agriculture use. It should also be noted that in the last years, tourism has developed as a strong industry for Morocco's economy.

Figure 13. Economic activity map of Morocco



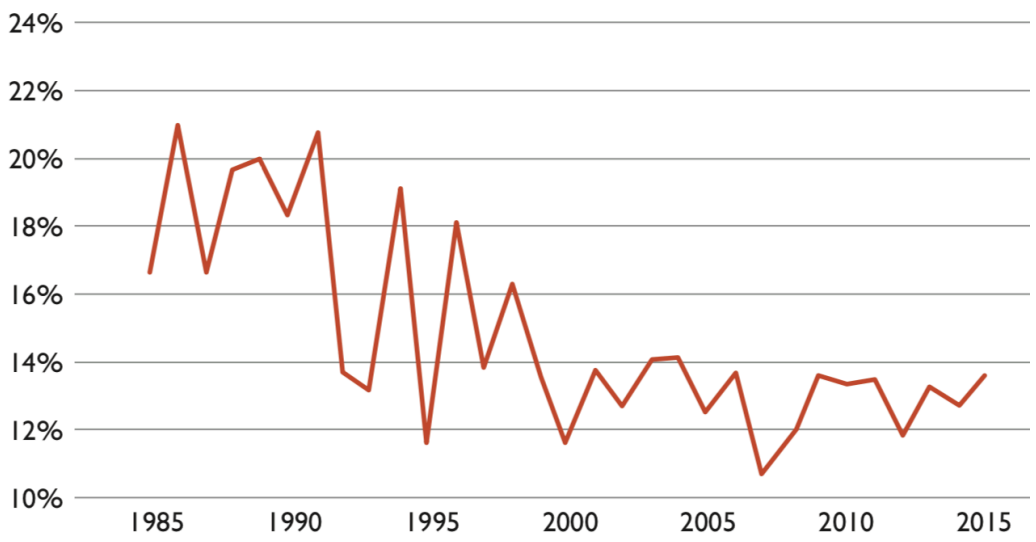
Source: https://www.mapade.org/marruecos.html.

4.2 Sectorial Snapshots

4.2.1 Agri-Food Sector[41]

The agricultural sector (including livestock) accounts for roughly 15% of Morocco's GDP, 23% of its exports, over 30% of its total employment (generated by agriculture and agribusiness activities). As it can be seen in Figure 14, from 2000 to 2015, agriculture was the fastest growing sector in the country (World Bank, 2016) and nowadays, agro-industry is the country's second largest industrial subsector. It represents 5% of the total GDP and 27% of the industrial GDP. The sector's value added is around USD 3$billion (MAD[42] 30billion). The agribusiness sector employs up to 143.000 people and gathers 2.050 industrial units (mainly SMEs). The agribusiness' products are mostly consumed domestically; exported goods only account for 12% of the total industrial exports.

Figure 14. Agricultural Value Added as a Share of GDP. 1985-2015



Source: World Bank 2016d.

As can be depicted from the graph above, Morocco's economic growth has become more resilient to the climate in the past decades. Agricultural value added currently accounts for less than 14% of the national GDP. The decline in the impact of agricultural economic outcomes on the total economic growth also relates to the diversification of the economy, which has overall reduced the agriculture share in its GDP. The graph above shows how the agriculture's share of the total GDP decreased from almost 20% during the 80s to 15% on average during the 90s, and to 13% since 2007.

[41] This overview is largely drawn from World Bank (2017) and 'Our Africa, Morocco – Climate and Agriculture', http://www.our-africa.org/morocco/climate-agriculture.
[42] MAD - Moroccan Dirham (Morocco's currency).

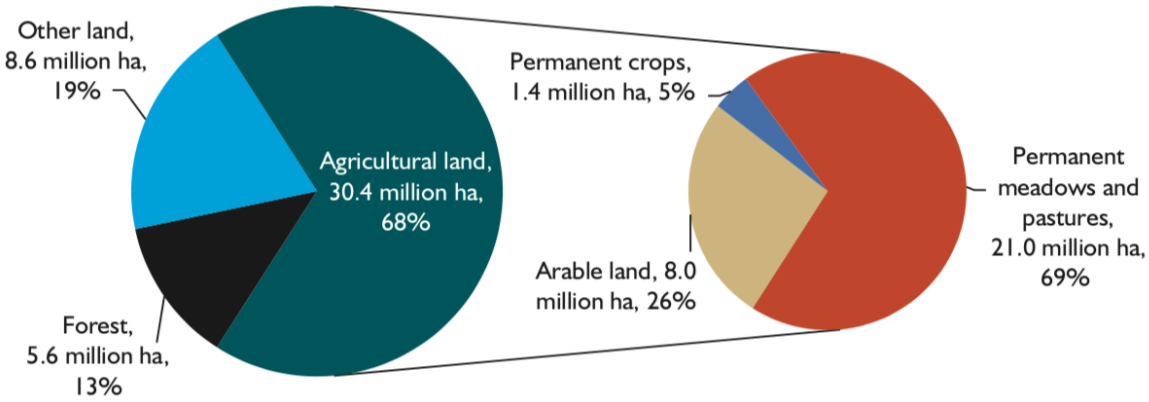
Agricultural Land Use in Morocco

From an agro-ecological point of view, two main groups of land can be distinguished:

- The favorable areas: plains and hills with a pluviometry above 400mm; and large irrigated perimeters which have a remarkably high productivity potential, but do only represent ¼ of the farms on the 1/3 cultivated areas.
- The most difficult areas: semi-arid plains and agricultural plateaus, oasis, mountains and steppes (HCP, 2007).

As shown in the pie-chart below (see Figure 15), the majority of the arable land in Morocco is dedicated to agriculture, with the rest in forest or other uses. Agricultural land use statistics indicate that around 8 million hectares are arable, while 1,4 million hectares are dedicated to permanent crops and 21 million hectares are in permanent meadows and pastures. The area of permanent crop in Morocco grew a 46% between 2008-2013 in response to the GoM efforts to promote higher value and commercial agriculture, including citrus and olives.

Figure 15. Morocco Land Use



Source: FAOSTAT 2013.

Plateaus and coastal plains provide the main growing areas for Morocco's commercial agriculture. The warm climate and rain patterns allow the production of winter wheat and barley, with fruits and vegetables (grapes, olives, etc.) cultivated during the summers.

Out of all the crops cultivated in Morocco, cereals are planted on 43% of the area, 3% is dedicated to pulses (beans, etc.), 7% to commercial plantation type crops (such as almonds, grapes, citrus, olives, and dates), 2% to industrial crops (cotton, sugar beets and oilseeds, sugar cane), 2% to forage, and 2% to vegetables, while

41% of the land generally remains fallow[43]. Dates are produced in oases in the dry regions of the country (in the south), fed mostly by underground tunnels from the mountains. Strengthening the country's irrigation is supporting the production of export crops such as tea, sunflowers, sugarcane, tobacco, cotton and soybeans. Livestock-rearing -sheep, cattle, and goats- is well extended, and provides local consumers with meat and dairy goods. The country's agriculture has been notably diversified as a way of climate change adaptation. Despite the fact that cereal production remains dominant, there is a rising trend towards livestock production and horticulture.

Food imports and exports

The country's key agricultural exports include vegetables[44], citrus[45], vegetables, almonds, olives and olive-oil, dairy products[46], and more recently, blueberries, cherries and asparagus. More specifically, Morocco was the world's 2nd largest exporter of table olives, 4th largest exporter of tangerines/mandarins, 5th largest exporter of olive oil, and 11th largest exporters of oranges in 2013[47]. However, early season vegetables and specialty crops such as Argan, have the highest value for export. Morocco has an advantage in some crops, namely citrus, melons, grapes, peppers, tomatoes and strawberries, mainly to be exported to European and African markets.

The country cultivates food and produces products for both the national market and to export, however the increasingly frequent droughts challenge both the balance of payments and internal food security. Even in the years without droughts, Morocco spends 20% of its export revenues on food imports, which is around four times the world average[48]. The most imported agricultural products are grains, tea, sugar and coffee, together with basic food grains in drought years.

Revenues derived from exports are critical for food security, as cereal imports are key in drought years. In order to incentivize the production, agriculture production is fully exempted from taxes[49].

[43] Global Yield Gap Atlas, *Country Profile: The Kingdom of Morocco*, http://www.yieldgap.org/morocco
[44] e.g., peppers, tomatoes, green beans.
[45] Particularly oranges.
[46] Mainly cheese.
[47] Morocco produced some 1.6 million tons of olives and 2.2 million tons of citrus in 2014, while between 2008 and 2014 the harvested area in olives increased by 74% and that in citrus by 24% (World Bank 2017).
[48] Hafez Ghanem, *Agriculture and Rural Development for Inclusive Growth and Food Security in Morocco*, Working Paper 82, Brookings Institute, February 2015, https://www.brookings.edu/wp-content/uploads/2016/07/Agriculture_WEB_Revised.pdf
[49] Morokko-Info, *Agriculture and Fishery*, http://www.marokko-info.nl/english/agriculture-and-fishery

Women in farming

In 2014, poverty rates were roughly six times higher in rural than in urban areas. In addition, more than 19% of the rural population is vulnerable to poverty[50]. Consequently, the rural population accounts for more than 79% of the poor and 64% of the vulnerable, particularly women and youth. Women's work on subsistence farms, moreover, is often unpaid or unrecognized. About 73% of female labor in the primary sector is unpaid, a share that is even higher than the 60% unpaid labor rate for youth.

Farming is the main source of income in rural areas; therefore, improving the prospects of the rural poor requires sustainable farming practices and higher farm incomes. For instance, a local transformation through agroindustry, and improving agriculture's value chain commercialization practices would ensure a better sector performance, leading to higher incomes and a consequent reduction of poverty.

Institutional Framework of Morocco's Agro-Food Sector

Table 5. Institutional Framework of Morocco's Agro-Food Sector

Agency	Function
Ministry of Agriculture and Maritime Fisheries [51] (MAPM) ↓ **9 Regional Offices for Agricultural Development (ORMVAs)**	ORMVAs are public institutions with financial autonomy and legal personality. Their mission includes development of land consolidation works, the creation and operation of irrigation and drainage infrastructure, and management of agricultural water resources use in their geographic areas of jurisdiction. They also participate in the training of farmers. They are likewise responsible for operational management of drip irrigation activities in irrigation systems conversion projects under the general supervision and control of the Ministry of Agriculture and Maritime Fishing.
Agricultural Development Agency (ADA)	ADA was created to guide the implementation of the government's agricultural development strategy. It is responsible for proposing action plans in support of agricultural subsectors with high value added in order to improve their productivity. Its main tasks are to find and mobilize land for the expansion of agricultural production and the development of high-value crops. It encourages the development of agricultural products through the introduction of new irrigation systems, farm equipment, better packaging, and improved marketing. It supports the promotion of agricultural investment and implementation of partnerships with investors. ADA is also responsible for proposing action plans to support agriculture

[50] Vulnerability to poverty is the share of the population whose per capita consumption is in the range between the poverty line and one and a half times that threshold.

	solidarity through the promotion and implementation of economically viable projects to improve farmer incomes.
National Office of Agricultural Extension Services	Developed in 2010 to support the implementation of the PMV[52], the government's agricultural extension strategy aims at a progressive empowerment of and stronger accountability to farmers. In order to achieve this objective, the government regulates and stimulates the development of the private agricultural extension services while remaining guarantor of a local public service to farmers. Private actors are empowered to relay the action of the state. Implementation of the strategy relies on the redesign of the advisory and guidance activities. The first action taken in this regard was the creation of ONCA in 2013. ONCA's actions are based on new channels of transmission and knowledge management; including farmer field schools, virtual network knowledge, call centers, and production and distribution of audio-visual materials.
Chambers of Agriculture	A new role was also assigned to the existing Chambers of Agriculture. This involves: (1) participating in the governance of the system of agricultural extension services; (2) promoting agricultural organization and raising awareness of farmers in forming groups; (3) con- tributing to feeding into the knowledge management system by collecting best practices to farmers; and (4) contributing to the development and implementation of agricultural development projects that meet the needs of farmers.

Source: Own creation.

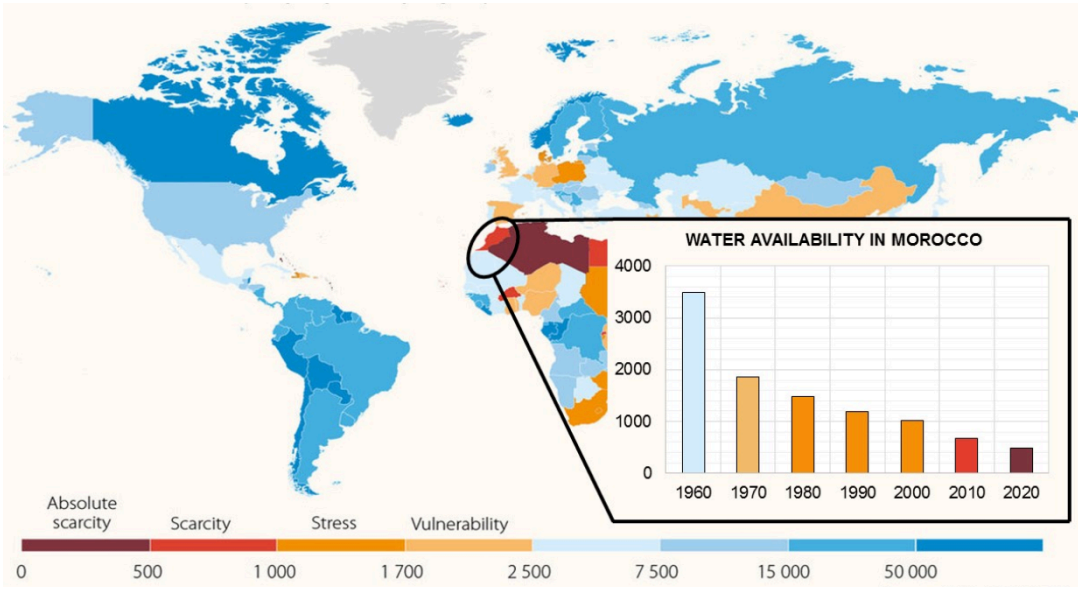
4.2.2 Water Resources

Sectorial Context

Water is another crucial resource in Morocco and, alike food production, water is under strong pressure because of climate change[51]. According to the United Nations Economic Commission for Africa (UNECA), Morocco is already in a condition of water stress[52]. By 2025 Morocco's water security will worsen, bringing it into a condition of water scarcity[53].

The World Resource Institute (WRI) has ranked Morocco 22nd in the world to face high baseline water stress. The MENA region is home to ¼ of the world's population, and 12 out of the 17 most water-stressed countries are in the region. For instance, in 2015 Morocco faced a severe drought that had a terrible impact on its agriculture, consequently affecting its economy: the following year, in 2016, Morocco faced an economic decrease of 1.5%.
Figure 16 shows how countries compare in terms of water availability.

Figure 16. Water availability, m3 per person per year



Source: FAO Aquastat, 2011.

As a result of an annual 1,5% population growth, a yearly economic growth of 4%, successive droughts and the reduction of rainfall by 30%, there has been an increasing pressure on water resources in the past years, having a direct impact on groundwater availability and on agriculture production. Meanwhile, water demand is growing, leading to exploitation beyond the amount of available renewable water, resulting in groundwater depletion. Due to all these pressures, improved levels of water efficiency need to be reached.

[51] OCP Policy Center. Nexus of Water-Energy-Food as an approach to face Climate Change. Policy Brief, March 2018. PB-18/06.
[52] *Water stress* defined at 1.000m3 to 1.700m3 of available freshwater per person per year.
[53] *Water scarcity* defined at less than 1.000m3 of available freshwater per person per year.

Water resources

Morocco is drained by 6 large sets of hydrographic basins, as detailed in Table 6.

Morocco's watersheds: exploitable surface area and water resources

Table 6. Morocco's watersheds: exploitable surface area and water resources

WATERSHED	Surface (km2)	Exploitable Surface waters (millions of m3)	Exploitable Underground Waters (millions of m3)	Total exploitable water (millions of m3)
Northern Rifain Basins • **Loukkos-Sud Larache** • **Tangérois** • **Coastal Basins**	**20.600**	**3.600**	**190**	**3.790**
Northern and Center Atlantic Basins • **Sebou** • **Bouregreg and Atlantinc Costs** • **Oum Rbiaâ et côtes Jadida Safi** • **Tensift et côtes Safi - Essaouira**	**133.340** 40.000 20.470 48.070 24.800	**10.525** 5.560 850 3.315 800	**2.345** 1.300 120 405 520	**12.870** 6.860 970 3.720 1.320
Southern Basins – West Atlantic • **Souss-Massa** • **Daraâ**	**126.480**	**1.444**	**691**	**2.135**
Eastern Basins • **Moulouya**	**76.664**	**1.160**	**512**	**2.122**
South Atlas Pre-Saharan Basins • **Guir-Bouanane-Tamelelt** • **Ziz-Rhéris-Maïder**	**58.841**	**626**	**313**	**939**
Other Saharan basins	**30.625**	**-**	**-**	**-**
TOTAL	**446.550**	**17.805**	**4.051**	**21.856**

Source: Own compilation of data from MEMEE, 2009 & FAO 2015.

Surface water resources are very unequally distributed throughout the country: Loukkos, Sebou and Oum Rbiaâ basins account for 71,5% of the national resources.

On the other hand, underground water resources are relatively better distributed over the territory. Of the 96 aquifers in the country, 21 are deep aquifer and 75 are superficial. The most important aquifer systems cover a total area of nearly 80.000 km2, which accounts for the 10% of the territory (MEMEE, 2009).

Out of all renewable water resources[54], the potential resources to be exploited under the current technical and economic conditions are estimated at 22 km3/year –18 km3 of surface water and 4 km3 of groundwater (MEMEE, 2011)- of which more than 1 km3 comes from the return of irrigated water by surface water (Plan Bleu, 2011). Moroccan water resources are variable in space (more than half of the exploitable resources are distributed in the northern river basins, covering just 7% of the national territory) and time (precipitation can vary from 5 to 50 billion m3 - BCM- over the years).

In order to manage this geographic and temporal variability, Morocco has traditionally focused on the storage of surface water. Dating back to the 60s, an important hydraulic heritage was initiated to mobilize surface water resources through large water retention dams, conveyance systems, water supply and irrigation infrastructures, as detailed below:

- 135 large dams with a total capacity of 17,500 M m3. The silting up of dams is estimated at nearly 75 M m3 / year on all the large dams in the country, thus limiting the amount of water that can be mobilized. A storage capacity of 2,600 M m3 will soon be added with 14 large dams under construction (CES, 2014)[55].
- To these large dams must be added 100 small dams which aim to meet local needs for drinking water, irrigation and watering livestock. The total capacity of small dams is estimated at nearly 100 M m3;
- 13 water transfer structures between watersheds, with a total length of 785 km allow more than 2,700 M m3 to be transported;
- A large network of boreholes, wells and spring catchments that allow the mobilization of nearly 4 billion m3 of groundwater each year.
- Surface water is also used by water withdrawals using traditional diversion works, particularly in mountain regions. These abstractions are estimated on average at 1.700 M m3 / year (MEMEE, 2011).
- Nationally, 120 important natural lakes are inventoried, the majority of which are located between the two mountain ranges of the Middle Atlas and the High Atlas. On the coast, there are lagoons and coastal marshes (MEMEE, 2010).

Water Use

The comparison between the mobilized water resources and the water demands of the different sectors shows that the needs are not met and that there is a water deficit of approximately 4.000 M m3, of which approximately ¼ comes from the overexploitation of aquifers (CSEC, 2014).

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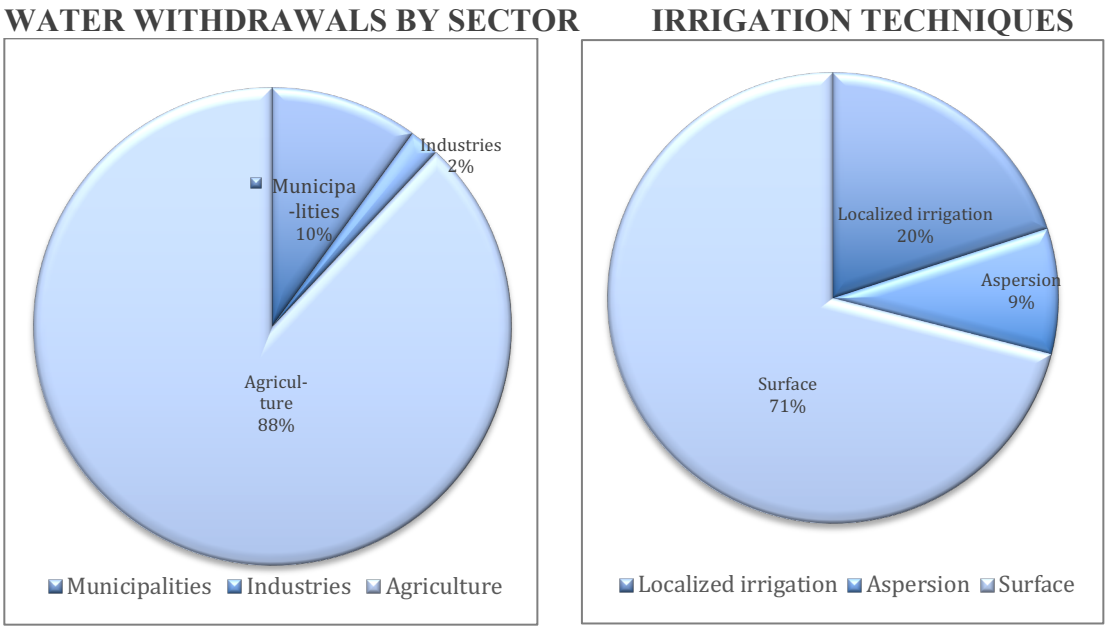
[54] *Wastewater:* In terms of unconventional water resources, municipal wastewater is estimated at 640 M m3 in 2010 (MEMEE, 2013), and more than 90% of it discharged into the natural environment without prior treatment (MEMEE, 2010). The potential of municipal wastewater should reach 1,039 million m3 by 2030 (HCEF, 2010), of which the direct use after treatment is estimated at 325 million m3 in the same year (MEMEE, 2013; CSEC, 2014). The direct use of municipal wastewater treated in Morocco nowadays concerns around 550 ha of agricultural land, to which must be added the watering of golf courses and green spaces (FAO et al, 2011).

[55] More detailed information on the dams can be found under Annex III.

Figure 17. Water withdrawals by sector, and Irrigation techniques graphs



Source: Own compilation of data from Aquastat Report, FAO 2015.

Since the establishment of the MPV in 2008, localized irrigation has greatly increased and is gradually replacing surface and sprinkler irrigation thanks to subsidies dedicated to this transition policy aimed at saving agricultural water. The average annual increase in localized irrigation was around 9% over the period 2002-2007 to 16% over the period 2007-2011.

1/3 of the irrigation water comes from groundwater, and 2/3 from surface water, half of which comes from water stored in dams and the other is taken over the water on average from the period 2006-2011 (FAO, Aquastat Report 2015).

Desalination

Nowadays, the use of seawater desalination and the demineralization of brackish groundwater for the supply of drinking water to cities is limited to the Saharan areas of southern Morocco. The capacity was around 13.11 million m3 in 2011 (35,910 m3 / day including 5,030 m3 / day of brackish water demineralization; CSEC, 2014), but should increase to 400 M m3 by 2030, according to the national water strategy (Plan Bleu, 2011).

For this purpose, new factories have been installed: in Agadir (Jariri, 2009), Sidi Ifni and Tantan (10.000 m3/day) (CES, 2014). In addition, the GoM has recently announced its plans to build the world's largest seawater desalination unit for irrigation and drinking water. The project will provide daily 150.000m3 of desalinated drinking water along with 125.000m3 of desalinated irrigation water. High voltage power lines transporting electricity from the Noor Complex will

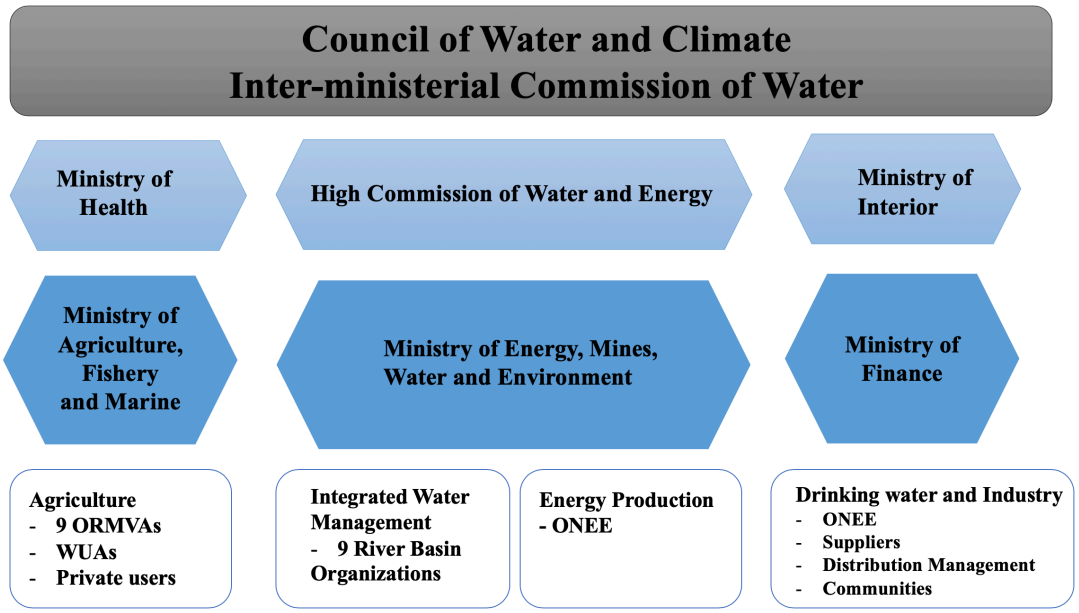
power the desalination process and the project seeks to eventually increase its daily production to 450.000m3[56].

The Agadir desalination project is "pioneering integrated approaches to tradeoffs of sustainable water, energy and food management in Morocco and its success could lead to best practices for renewable energy powered desalination plants across the Middle East and Africa, home to many of the world's most water insecure countries", points out the Policy Center for the New South (2018).

Water Management

In Figure 18 below there is a graphic representation on the organizational map in charge of the management of water in Morocco.

Figure 18. Organizational map for the management of water



Source: Own compilation of data from Aquastat Report, FAO 2015.

Water management in Morocco has been long characterized by a supply-oriented management, based upon the major hydraulic infrastructures that were built after Morocco's independence. Since 2009, with the implementation of a new national water strategy, this has evolved. The new strategy is based upon the 3 pillars described below.

1. Demand management:
   - The promotion of the economy and the enhancement of water mobilization through massive conversion to localized irrigation thanks to the National Economy Program.

[56] The World Bank, 2016. *5 Things Morocco is doing about Climate Change.* https://www.worldbank.org/en/news/feature/2016/11/17/5-things-morocco-is-doing-about-climate-change

- Water for Irrigation (through the PNEEI[57]), and improving the hydraulic efficiency of urban distribution networks and irrigated areas; pricing and assistance with irrigation management.

2. Offer management:
   - Strengthening the mobilization of conventional water resources (in particular surface water) with the construction of new dams'; the mobilization of unconventional water resources, in particular through the desalination of seawater and demineralization of brackish water.

3. Preservation of water resources:
   - Control of new drillings and regularization of old drillings. The ban on drilling is defined by groundwater agencies, when considered to be over-exploited (AfDB, 2011).
   - Protecting: oases, wetlands and watersheds (through the PNABV[58]).
   - Flood control (through the PNPCI[59])

User participation was also introduced in 1992, through the creation of 1.200 Agricultural Water User Associations (AUEA[60]) to allow the participation of water users in the construction of the new network for irrigation and also, to make them accountable for its maintenance. Depending on the type of perimeter, the distribution of irrigated water differs[61]:

- Private irrigation perimeters: they program their management in an autonomous way, mobilizing independent water resources. The volumes and flows that can be withdrawn are set and controlled by public water authorities.
- Small and medium hydraulic perimeters: the planning and the organization of the irrigation are done according to the water flow imposed by the AUEA. This association is also responsible for the maintenance of the equipment.
- Large hydro perimeters: In these cases, it is ORMOVAs who provides water services to farm managers. These perimeters, as well as the modern small and medium hydraulic perimeters, are equipped with devices to self-regulate and measure the flow and volumes of water delivered.

A new tool, *Groundwater Contracts*, has been developed between the administration and the AUEAs, for the most overexploited aquifers in order to safeguard the resource and the uses that depend on them.

Women in irrigation

A study on the role of women in managing water resources, and in particular agricultural water carried out in the perimeter of the Gharb river basin (Morocco),

[57] PNEEI - National Irrigation Water Saving Programme *(Programme National d'Economie d'Eau en Irrigation)*.
[58] PNABV- National Watershed Management Plan *(Plan National d'Aménagement des Bassins Versants)*.
[59] PNPCI - National Flood Protection Plan *(Plan National de Protection Contre les Inondations)*.
[60] AUEA - *Associations d'Usagers des Eaux Agricoles.*
[61] FAO, Aquastat Report 2015.

shows that irrigation results in an overload of work for women, whose nature is unrelated to irrigation, such as weeding and animal husbandry. This is due to the labor-intensive nature of the irrigation production systems, necessitating a reorganization of work and a new distribution of tasks.
Of the women surveyed, 16% said they had been involved in irrigated crop tasks for more than 5 years, while all 31 farms surveyed had irrigation. Their contribution to irrigation is limited to the maintenance and cleaning of irrigation canals and the movement of irrigation equipment.
Unlike other areas surveyed in this study, 28 out of 31 women do not appear to benefit from the adoption of new irrigation techniques such as localized irrigation[62]. In addition, they are generally not members of irrigation associations even when they are the farm managers (FAO, 2014).

Institutional Framework of Morocco's Water Sector
Three ministerial departments are directly concerned with the water sector, each of them with its sectoral planning objectives in their respective fields.

Table 7. Institutional Framework of Morocco's Water Sector

Agency	Function
The Ministry of Energy, Mines, Water and the Environment (MEMEE)	- The **Department of Water (DE)**, previously integrated into the Ministry of Energy and Mines, but long managed by the Ministry Public Works -has been set up since 2013 into a ministry responsible for water. Its mission: research, evaluation, planning, development, and management of water resources, as well as the weather control with regards to climate change. It consists of 3 directions: ○ the general direction of hydraulics; ○ the management of hydraulic installations; and ○ the direction of water research and planning. - The **National Office for Electricity and Drinking Water: ONEE** (*Office National de l'Électricité et de l'Eau Potable)* and in particular its drinking water branch: the **National Office for Drinking Water** *(ONEP, Office National de l'Eau Potable)* which is responsible for supplying the country with drinking water and sanitation. - **9 Water Basin Agencies** (**ABH**, *Agences de Bassins Hydrauliques*), represent the Ministry at the regional level. They are administered

[62] *Localized irrigation* is a method of applying water that results in wetting only a small area of the soil surface and sometimes only part of the root zone. Water is applied near the base of the plant so that the application is concentrated in the root zone.

	by a board of directors, bringing together all the stakeholders concerned with the water issue. - **Water Services** represent the ministry at the provincial level.
The Ministry of Agriculture and Maritime Fisheries (MAPM)	- Counts with 9 **regional agricultural development offices (ORMVAs),** which are responsible for the agricultural development of the irrigated perimeters of large hydro. Their 3 fundamental missions are: planning, agricultural development and water service. - **The Provincial Directorates of Agriculture (DPA)** are responsible for the creation and monitoring of small and medium hydraulic perimeters outside the ORMVA action areas. They are only involved in the management of irrigation networks to carry out major maintenance work. - The **Agricultural Development Agency (ADA)** whose mission is to implement the government strategy for agricultural development.
The Ministry of the Interior (MoI)	- **Directorate of Water and Sanitation** - **Direction of management and conceded services**
Water User Associations (WUAs) ***Associations d'Usagers des eaux Agricoles (AUEA)***	Agricultural WUAs were created to organize participatory and integrated management of irrigation schemes and systems. These organizations operate in the areas of Big Hydraulic and Small and Medium Hydraulic perimeters (PMHs). They enter into agreements with the Administration concerning the planning of water resources, development and maintenance of the irrigation schemes. Such agreements specify the size and limit the scope of the WUAs, their work plans and their financial plans for investment, maintenance, operation, and servicing of hydraulic structures under their control.

Source: Own compilation of data from Aquastat Report, FAO 2015.

4.2.3 Energy Sector

Sectoral overview

Almost 91% of the energy used in Morocco is imported. Namely gas from Algeria; electricity from Spain; and oil, coal and petroleum products from the international markets. The country has just developed a limited quantity of national gas and no commercial sources of oil after many years of exploration (IEA 2014). The last coal mine in the north of the country stopped operating in 2004. The only domestic energy sources of Morocco are hydropower, biofuels and waste energy, which represent a very little percentage of the domestic electricity supply[63]. In order to meet the country's domestic electricity supply, Morocco relies mostly on fossil fuels[64]. In 2016 for instance, Morocco fulfilled most of its energy needs with oil (67.6%) followed by coal (16.1%)[65].

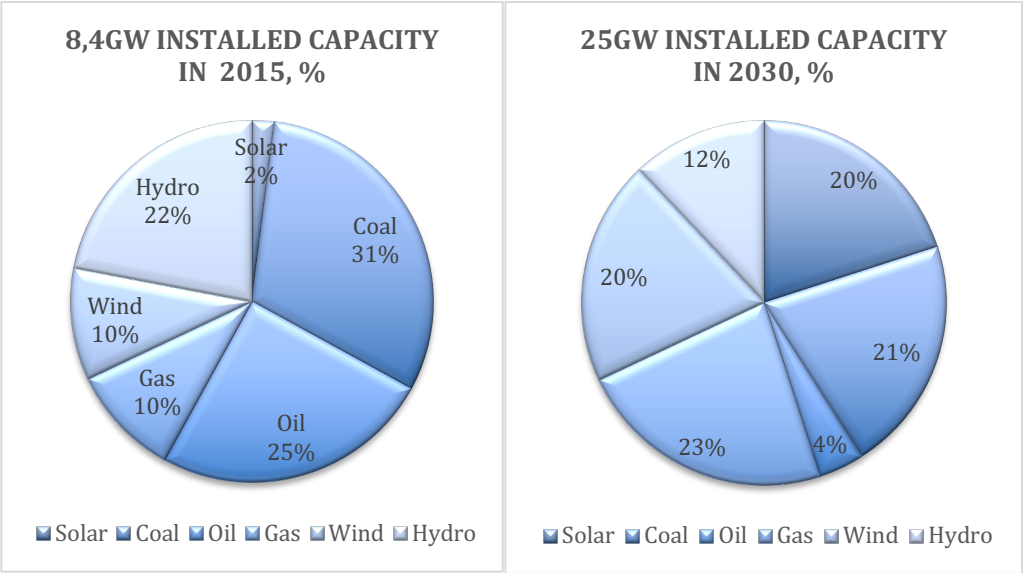
Given that Morocco has no domestic fossil fuel resources but instead has a rich renewable energy potential, shifting towards a low-carbon energy model might bring additional economic benefits, replacing the dependence on fossil fuels imports for national solar, wind, and hydroelectric power generation sources.

Morocco has recognized the importance of climate change for years, ratifying the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and the Kyoto Protocol in 2002. National targets for GHG emission reductions date back to the adoption of the National Energy Strategy in 2009 (IEA 2014). As stated in Morocco's Constitution, sustainable development is a right for all citizens. It literally says: *"make the territory and civilization more resilient to climate change while ensuring a rapid transition to a low-carbon economy"*. More recently, under the 2015 Paris Agreement, Morocco adopted an ambitious NDC[66], aligned with the country's commitment to implement climate policies.

The GoM is already changing its future energy mix by supporting the development of renewable energy technologies. This shift is particularly important to face climate change and mitigate its impact and at the same time, is well aligned with the international community, under the common objective of reducing the carbon footprint and ensuring the sustainability of natural resources. Morocco plans to satisfy 52% of its energy needs from renewable sources by 2030, thereby reducing its dependence on fossil fuels. The country has also lifted all subsidies on diesel, gasoline and heavy fuel oil to encourage a more efficient use of energy and to mobilize investments in the transition to a green country and economy[67]. All these changes can be appreciated in Figure 19.

[63] Morocco Energy Policy MRV. *Emission Reductions from Energy Subsidies Reform and Renewable Energy Policy*. World Bank Group, June 2018.
[64] Morocco Country Profile. RCREEE (Regional Center for Renewable Energy and Energy Efficiency). https://www.rcreee.org/content/morocco
[65]Relief Web. Predicted freshwater stress and scarcity in Africa and the Middle East. https://reliefweb.int/map/morocco/predicted-freshwater-stress-and-scarcity-africa
[66] Morocco NDC – Morocco's Nationally Determined Contribution under the UNFCCC (Paris Agreement).
[67] German Watch. Country Fact sheet Morocco. Mena-Select, 2016

Figure 19. Installed Capacity Graphics, from 2015 and 2030 (%)



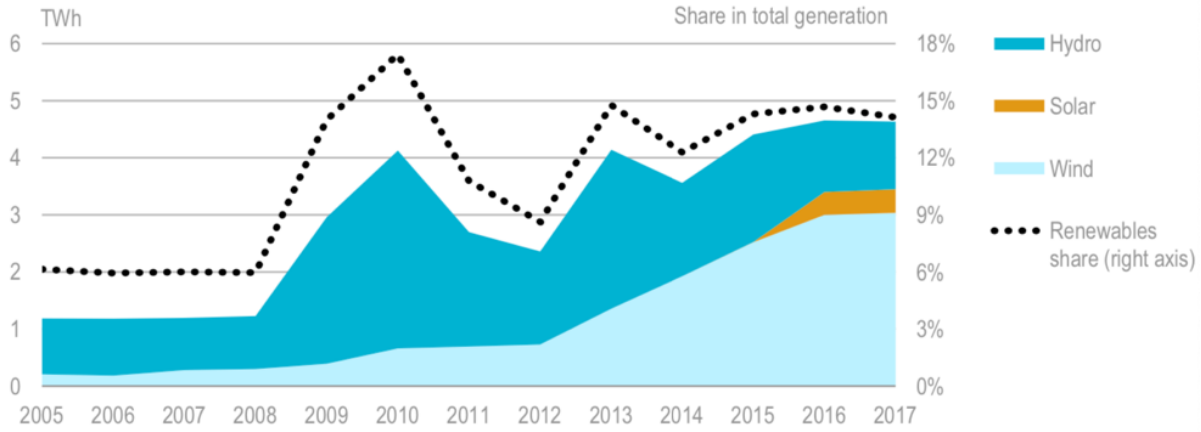
Source: Own compilation of data from the World Bank, 2019.

Morocco has significantly increased its renewable electricity generation[68] over the past decade. In 2017, the total power generation from renewable sources (4,6TWh) was three times higher than in 2007[69]. Wind power became the largest renewable power source, with a rapid increase on its generation capacity from 0,3 TWh in 20017 to 3,0 TWh in 2017. In recent years, Morocco has also installed large concentrated solar power (CSP) plants, and solar has become another important power source. However, solar still plays a very small role for the large potential it entails, representing a 1,3% in the power mix, as can be appreciated in Figure 20. Hydropower has shown a different trend; despite the stable capacity installed, the actual contribution of hydro in the power generation capacity has varied significantly during the past years as water availability and precipitation levels have fluctuated. In fact, the government of Morocco has highlighted the decrease in water availability as one of the key impacts of climate change (GoM, 2016), raising concerns about the future of hydropower generation in the longer term.

Morocco's main energy-related vulnerabilities include the dependence on electricity imports (which is declining but still persists), fossil fuel price fluctuations (critical for imports), and a territorialized electricity distribution model that could be disrupted by the integration of renewable energy into the grid.

[68] Differentiation should be made between energy capacity and energy generation. *Energy capacity* refers to the maximum output of electricity that a generator can produce under ideal conditions and measured in MW, kW or GW; whereas *energy generation* refers to the amount of electricity that is actually produced over a given period of time, and is measured in kWh, MWh, TWh, etc.
[69] IEA (2019 forthcoming), World Energy Balances 2019 preliminary edition, www.iea.org/statistics/

Figure 20. Renewable Energy and Waste in Electricity Generation (2005-17)



Source: IEA, 2019.

Energy Transition

Morocco's case of power sector reforms represents an interesting success story that undertook a different institutional path from the model prescribed in the 90s[70]. It created its own differentiated way for the transition of its power sector: Morocco introduced selected private sector participation to increase electricity distribution and generation capacity, whilst keeping a vertically integrated state-owned national power utility operating as a single buyer at the core of the sector (World Bank, 2019).

In order to support economic development, the GoM gradually reduced its dependence on fossil fuel imports and at the same time relieved the fiscal pressure on renewable energy, positioning itself as the regional leader in sustainable energy. Truth being said, the results have been spectacular:

- Since the 90s, the country's power supply has been multiplied by three. Morocco's renewable energy power supply has also been strengthened, representing 1/3 of the total and private sector investments account for more than 50% of the electricity generated.
- The 2009 National Energy Strategy set out the objective of having 42% of renewable energy out of the total installed capacity by 2020.
- In 2015, Morocco submitted its Nationally Determined Contribution[71] (NDCs), setting the objective to reach a 52% of the installed electricity generation capacity from renewable sources by 2030, implementing the Paris Agreement (COP21).

[70] The 90s model of power sector reforms was based on the "Washington Consensus"; on improving economic efficiency and attracting private investment. These reforms are comprised of four distinct measures: restructuring, regulation, private sector participation and competition (Foster, Witte, Banerjee, & Vega Moreno, 2017; Bacon, 2018).

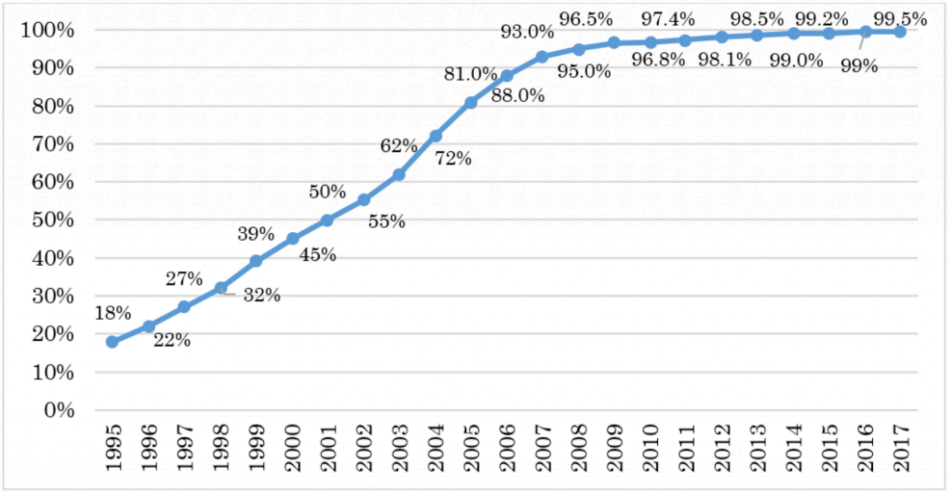
[71] Nationally Determined Contribution of Morocco. Presented to the UNFCCC on June 5th, 2015. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Morocco%20First/Morocco%20First%20NDC-English.pdf

- Morocco announced an additional plan to reach the 2030 target, adding 10GW of renewable energy between 2018 and 2030, divided as follows: 4.560MW of solar, 4.200MW of wind and 1.330MW of hydropower capacity[72].
- In 2018, the GoM announced its renewable energy penetration plan to go beyond 52% in their energy mix.

The GoM has also made major progress in greater objectives of the energy sector such as:

- Rural electrification: it achieved about 99.5% rural electricity access in 2017 for 2.1 million households, up from 18% in 1995[73].

Figure 21. Rural Electrification (1995-2017)



Source: World Bank, 2019.

- Low-carbon transition: the GoM implemented a renewable energy strategy aiming at decarbonizing its energy mix: renewable energy – including hydro, solar and wind– represents 34% of the installed generation capacity, a higher percentage than some OECD countries[74].

Energy Consumption by Sector

Over the past decade, Morocco's energy consumption[75] increased significantly. The transportation sector is the biggest consumer, followed by the industry, along with

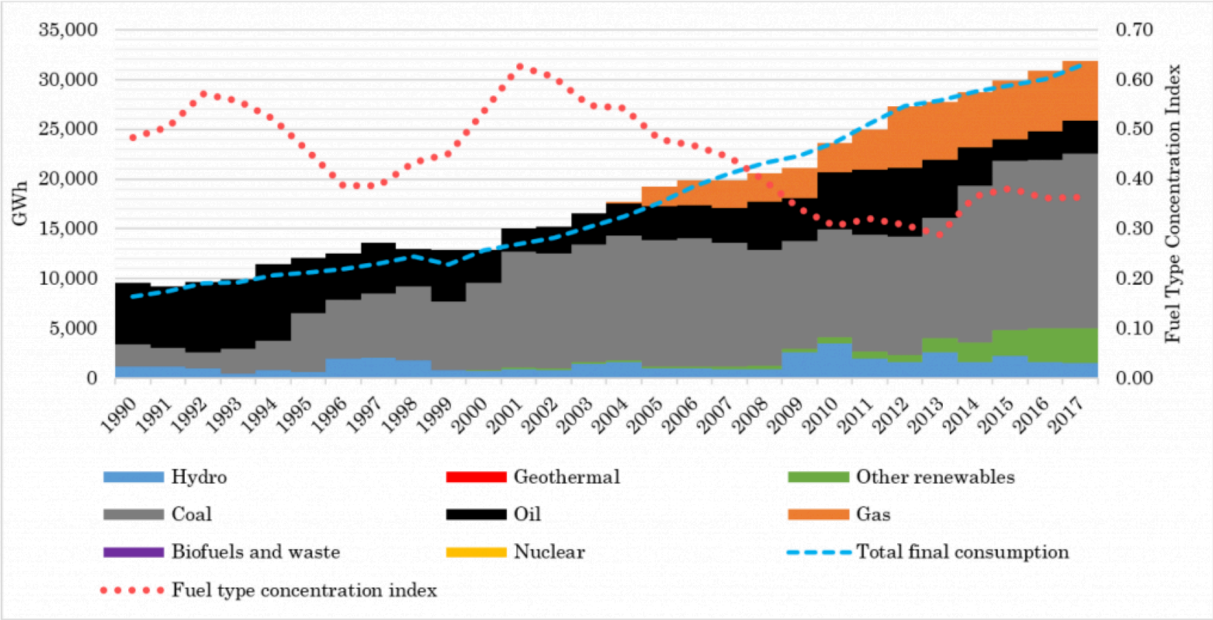
[72] Morocco bases its R.E. targets on installed capacity figures; in 2019 all capacity targets are being reviewed in order to optimize synergies between technologies. IEA, 2019.
[73] World Bank, August 2019. *'Lessons from Power Sector Reforms. The case of Morocco'.* http://documents.worldbank.org/curated/en/471511565200281012/pdf/Lessons-from-Power-Sector-Reforms-The-Case-of-Morocco.pdf
[74] Legislative framework for renewable energy in Morocco. https://www.renewableenergyworld.com/2019/03/10/legislative-framework-for-renewable-energy-in-morocco/#gref
[75] Oil is the largest fuel and electricity the second largest in all sectors except for commercial sector, where biofuels dominate. Morocco's Energy Policies, IEA 2019.

the residential sector and then, commercial and public services, finally followed by agriculture and forestry[76].

Electricity Generation

On the supply side, power generation in Morocco has more than tripled: from less than 10TWh in 1990 to 32TWh in 2017; whilst its capacity has almost doubled, from 5.233MW in 2005, to 8.820MW in 2017. This is largely thanks to the investments in the sector, that represent 50,8% of the electricity generation. The share of renewables in the energy mix has increased to almost 34% of its installed capacity[77].

Figure 22. Electricity generation in GWh (1990-2017)



Source: World Bank, 2019.

Women in Energy

Despite the fact that the A2030 has a particular SDG for Gender Equality (SDG 5), there still lacks exhaustive information on how to support gender equality and women empowerment within the energy sector[78].

In the case of Morocco, populations living in oases have seen their livelihood threatened by water scarcity and soil degradation as a result of climate change. Women are especially vulnerable to such effects due to the gender-roles established and the unequal distribution of resources and power between men and women.

[76] Energy Policies Beyond IEA Countries. Morocco 2019, IEA

[77] World Bank Blogs - November 19th, 2019. *'What Can Developing Countries Learn from Morocco's Experience with Power Sector Reforms?'* https://blogs.worldbank.org/energy/what-can-developing-countries-learn-moroccos-experience-power-sector-reforms

[78] '*Gender Equality for an Inclusive Energy Transition'*. IRENA (International Renewable Energy Agency), January 12th, 2019. https://www.irena.org/newsroom/articles/2019/Jan/Gender-equality-for-an-inclusive-energy-transition

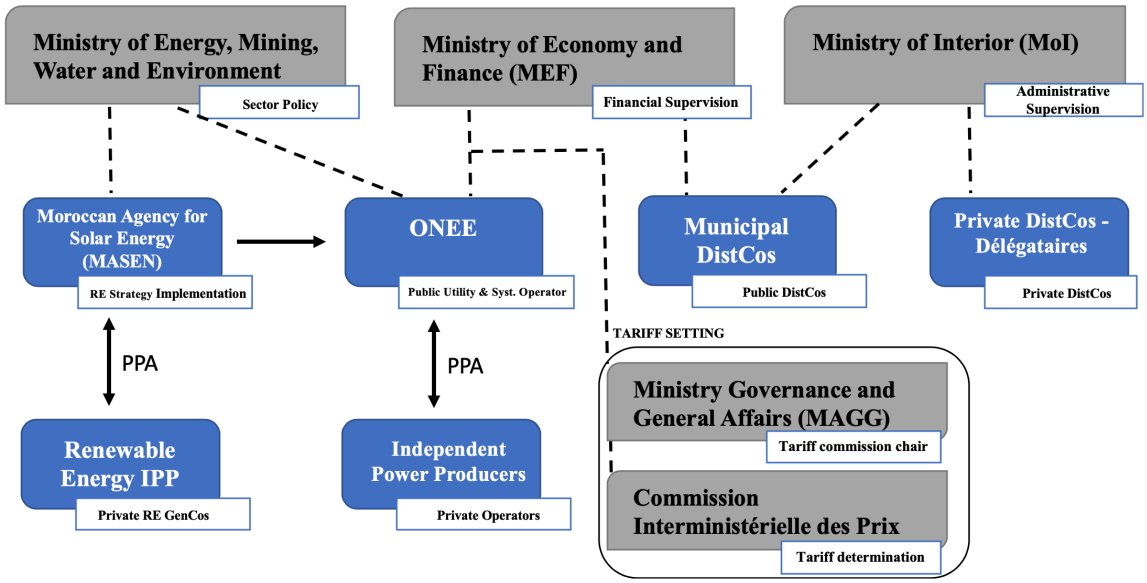
In the south-eastern province of Errachidia, women living in oases produce medicinal and aromatic plants with renewable energy sources, therefore contributing to climate change mitigation. A UN-Women Project allowed them to acquire a hectare of land to plant the seeds, and decided to use the drip irrigation method and a solar pump to cultivate their crops in the most sustainable way; as a result they have already seen their livelihood improved: in just two years, their incomes increased and they could open bank accounts, therefore achieving financial independence. This practice has already been spread to women from another oasis, such as in Tizagharine. With such practice, "they are not only able to earn a living, but they are also contributing to the resilience of the oasis ecosystem to better resist the threats posed by sprawling desertification and climate change"[79].

This is just another example that sustainable development within the framework of climate change is not possible without the full integration and participation of women.

Institutional Framework of Morocco's Power Sector

A map of the organizational structure of the energy sector, including both private and public sector entities, can be found in Figure 23 below.

Figure 23. Public and private entities in the energy sector



Source: Own compilation of data from IEA, 2019.

[79] 'In Moroccan oases women watch plants and incomes grow'. UN-Women, 2015. https://www.unwomen.org/en/news/stories/2015/9/moroccan-oases-women-watch-plants-and-incomes-grow

Table 8. Institutional framework of Morocco's power sector

Agency	Function
Ministry of Energy, Mines, and Sustainable Development (MEMDD)	This is one of the most important government agencies supervising the sector. MEMDD is responsible for Morocco's energy policy, including policy on renewable energy. It ensures the functioning of the electricity market, security of energy supplies, and the safety of people and energy facilities, among others. It drafts and enforces laws and regulations.
Ministry of Interior (MoI)	MOI supervises the private electricity distribution companies, the crosssubsidies in the sub-sector, as well-as participation in electricity tariff design and implementation.
Ministry of Finance and Economy (MEF)	MEF financially supervises all energy state-owned enterprises, including ONEE, MASEN, AMEE and SIE.
Ministry of General Affairs and Governance (MAGG)	MAGG leads an inter-ministerial committee on prices for determining and implementing tariff adjustments. The task of regulation and tariffsetting will shift to the new regulator, Autorité Nationale de Régulation du secteur de l'Electricité (ANRE).
The National Authority for Electricity Regulation (ANRE) ***Autorité nationale de régulation de l'électricité, (ANRE)***	ANRE was created in August 2018 with the mandate to organize the open and competitive segment of the electricity sector (ANRE's Director has already been appointed). ANRE's functions will include regulating access to networks, setting the tariffs for the utilisation of transmission and medium-voltage grid and ensuring the efficient functioning of the market. The Ministry of General Affairs will remain responsible for tariff setting in the regulated segment of the electricity market.
National Agency for Electricity and Water (ONEE)	ONEE is a state-owned, vertically integrated utility. It in charge of most generation activity, is the owner and operator of the transmission grid, performs the task of system operator and power dispatching and is the largest distributor and supplier of electricity. It is also in charge of producing power generation and transmission master plans. ONEE is supervised technically by MEMDD and financially by MEF.
Moroccan Agency for Energy Efficiency (AMEE)	AMEE was set up in 2010 as a successor to the Centre for the Development of Renewable Energy promotes energy efficiency Its main role is the implementation and coordination of energy efficiency programs. It also proposes national, sectoral and regional plans for energy efficiency

	development.
Moroccan Agency for Sustainable Energy (MASEN)	Is a limited Company with public shareholders responsible for the deployment of renewable energy. MASEN was established in 2010 to lead and manage the deployment of renewable energy. It develops the projects, raises the funds to finance them, and acts as a one-stop-shop. It also conducts renewables resource assessment, and generation capacity planning in collaboration with ONEE (IEA 2019, p. 109).
Municipal distribution companies	There are 11 distribution companies comprising of seven public municipal utilities and four private concessions. ONEE is also in charge of electricity distribution for most of Morocco's cities and regions. Municipal distributors are under the financial supervision of the MEF but are monitored in practice by the MoI. The private concessions hold a contractual relationship with municipal authorities.

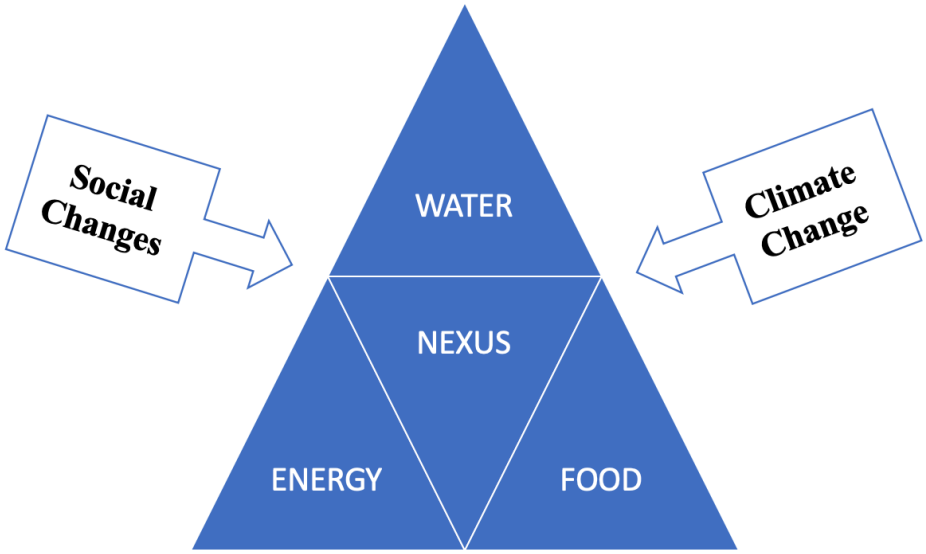
Source: Own compilation of data from IEA, 2019.

Chapter 5: WEF-Nexus Security in Morocco

5.1 Highlighted Nexus-related dependencies

In this section, a deeper analysis is conducted to the different bilateral interactions of the Nexus triangle edges (see Figure 24), for the particular case of Morocco.

Figure 24. Nexus-related dependencies



Source: Own creation.

Water in Energy (W⟷E)

- The water-energy Nexus is particularly critical when it comes to groundwater management in agriculture. Groundwater resources in Morocco are key in order to maintain agricultural revenues from which many families subsist. Such resources support the added-value of irrigated agriculture (representing 45% of the total agricultural value-added in normal rainfall years, but falls to 7% in drought seasons).
- Solar pumping, for instance, could reduce the energy costs for farmers by 2/3 (depending on the cost of fuel). However, such reduced costs may compromise the sustainability of aquifers, which are already overexploited.
- The GoM aims at improving the sustainability of groundwater resource planning so as to ensure the productivity of irrigated agriculture during water deficit years. It is noteworthy to underline that groundwater abstraction is possible thanks to subsidized energy prices, especially domestic butane, which was not targeted by recent petroleum product

subsidy reforms[80].

- The water sector legislation has been recently reinforced. The 2016 Water Law, improves the sustainable management of groundwater so that farmers can continue benefiting from the scarce and limited water resources. Women in rural areas are also expected to benefit from the Water Law (World Bank, 2018).
- Given that groundwater is completely dependent on pumping, energy prices have a strong effect on water use and irrigation. In this case, energy subsidies have a considerable impact on intensive groundwater use and aquifer depletion under water scarcity conditions (The World Bank, 2015).

Energy for Agriculture and Food production (E ⟷ F)

- A major approach to the Energy-Food Nexus is the Noor Complex, which consist on one of the world's largest Concentrated Solar Plants (CSP) located in Ouarzazate, which counts with a seawater desalination unit for irrigation and drinking water.
- Along with the *Agrovoltaic* solar-powered plant that will help agricultural production, the GoM hopes to use solar pumping solutions to allow larger farms to be self-sufficient' (Climateaction.org, 2019) which is an attempt to promote sustainable and effective energy that will in return help agriculture and production overall.

Water for Agriculture and Food production (W ⟷ F)

- Given that agriculture accounts for about 86% of the surface water withdrawals in Morocco, the ability for agriculture to continue to drive shared prosperity in rural areas is being threatened by the increasing weather variability and water scarcity[81].
- One approach of the GoM in trying to increase water productivity in agriculture has been the National Plan for Saving Water in Irrigation (PNEEI) which aims at updating water services to farmers by introducing efficient irrigation technologies (mainly drip irrigation). This plan is supported through the Agricultural Development Fund, with up to 100% subsidies for the adoption of drip and micro-sprinkler irrigation (under a maximum per hectare), and with 70% subsidies for sprinkler irrigation.
- While PNEEI targets a more efficient water use in agriculture, its impact on the overall water used depends on many other external variables. For instance, drip irrigation may allow farmers to obtain a higher production and value for the water used, but per se it does not control the amount of water

[80] In June 2012, GoM introduced a one-off increase in the price for unleaded gasoline and diesel fuel of 20 and 16% respectively, the sharpest single increase in fuel prices in over the previous decade. In early 2014, the Government decided to remove all subsidies for unleaded gasoline and Heavy Fuel Oil and to gradually phase out subsidies for diesel, representing 64% of the total amount (MAD 35.9 billion, equal to US$ 4.3 billion) that GoM paid in subsidies for petroleum products in 2013. In the 2015 budget law, the Government announced the termination of all diesel subsidies and the liberalization of liquid fuel market by end 2015.

[81] FAO, 2017. Water for Sustainable Food and Agriculture. http://www.fao.org/3/a-i7959e.pdf

used (which depends on pricing or quantitative restrictions). Drip systems provide farmers with a greater capacity of adaptation to restricted water scenarios as they have more control over the application of water. Something similar happens with groundwater; drip technology per se does not restrict water use, but easies compliance with restrictions.

5.2 Measuring the WEF Nexus

In order to build upon existing research lines, a thorough literature review was conducted to compare the existing tools to capture the WEF Nexus dimensions in a given country. It turns out there exist two broadly accepted indexes: the FEW Index (the Food-Energy-Water Index), which was developed by the Pardee Rand Graduate School in California USA; and the WFENI (Water-Food-Energy Nexus Index), which was developed by Inas El-Gafy.

The WFENI index's main objective is "to provide a method for decision makers to analyze the WEF Nexus of the crop production system" in particular. Instead, the FEW Index is based on the premise that "water, energy and food together are critical to social stability and economic growth. Insecurity in any one area poses serious impediments to human health, wellbeing, and development"[82]. For the purpose of this Thesis, the Pardee RAND FEW Index has been selected.

What does this index measure and how?
The Pardee RAND FEW Index[83] represents an aggregation of existing, publicly available data. It is an unweighted, geometric mean of 3 sub-indices that allows answering the following three questions:

- How "healthy" is a country's status of food, water, energy resources?
- What are the dominant sources of resource insecurity in a country?
- How can trends in society, technology, or the climate affect the security of food, water, and energy security in a country?

The FEW Index is calculated for each country based on 20 different measures that are combined to create the food, energy, and water respective sub-indices. Each sub-index is comprised of two or more indicators reflecting dimensions related to two factors:

1. Availability: Described as the extent to which a population is provided enough and adequate resources to fulfill their day-to-day needs.
2. Accessibility: Defined as how these resources are distributed across a given population.

[82] See: https://www.prgs.edu/pardee-initiative/food-energy-water/about.html
[83] For further explanation of its technical documentation, please see: https://www.prgs.edu/pardee-initiative/food-energy-water/about.html

Based on the RAND Pardee report description, energy availability is defined as a situation in which "nation's electricity infrastructure meets the needs of individuals to promote human development" and the energy accessibility is defined when "individuals have access to modern forms of energy for residential uses, including electricity, modern heating and cooking fuels, etc.".

In the case of water security, the index considers a third additional variable together with availability and accessibility: 'water adaptive capacity' defined as the availability of water resources to meet new needs or compensate for declines in existing sources" (Willis et al., 2016).

As it can be seen below, the three sub-indices are computed using formulas based on the geometric mean of the selected variables for each resource:

Food Sub-Index = $\sqrt{(\boldsymbol{Food\ Availability})\ \boldsymbol{x}\ (\boldsymbol{Food\ Accessibility})}$

Energy Sub-Index = $\sqrt{(\boldsymbol{Energy\ Availability})\ \boldsymbol{x}\ (\boldsymbol{Energy\ Accessibility})}$

Water Sub-Index = $\sqrt[3]{(\boldsymbol{W.Availab.})\ \boldsymbol{x}\ (\boldsymbol{W.Access.})\ \boldsymbol{x}\ (\boldsymbol{W.Adapt.Capacity})}$

To compute the sub-indices, values have been normalized as shown below, in order to relate the bigger values with higher security levels and the lower ones with insecurity levels.

$$\boldsymbol{Value} = \frac{(\boldsymbol{Actual\ Value - Logical\ Minimum})}{(\boldsymbol{Logical\ Maximum\ Value - Logical\ Minimum})}$$

Finally, the FEW Index is calculated as follows:

FEWi = ***Food, Energy and Water Index***
Fi = ***Food Sub-Index***
Ei = ***Energy Sub-Index***
Wi = ***Water Sub-Index***

$$\boldsymbol{FEWi} = \sqrt[3]{(\boldsymbol{Fi})\ \boldsymbol{x}\ (\boldsymbol{Ei})\ \boldsymbol{x}\ (\boldsymbol{Wi})}$$

Using a numerical tool to dimension the Nexus also allows comparing the WEF Nexus resilience of a country vis-à-vis other countries within the same region, as it is done in the next section of this chapter.

How does Morocco score?

Morocco's FEW value[84] is 0,53 -which puts the country in the medium water, energy and food nexus security category. Morocco is performing almost at the same level of the other countries in the MENA region, that have an average FEW Index of 0,54; and significantly better than the 0,37 average of its Sub-Saharan neighbors, as it can be appreciated in Table 9. Morocco's rank is shared with countries such as Libya or Bolivia (both also scoring 0,53).

Morocco's FEWi = 0,53

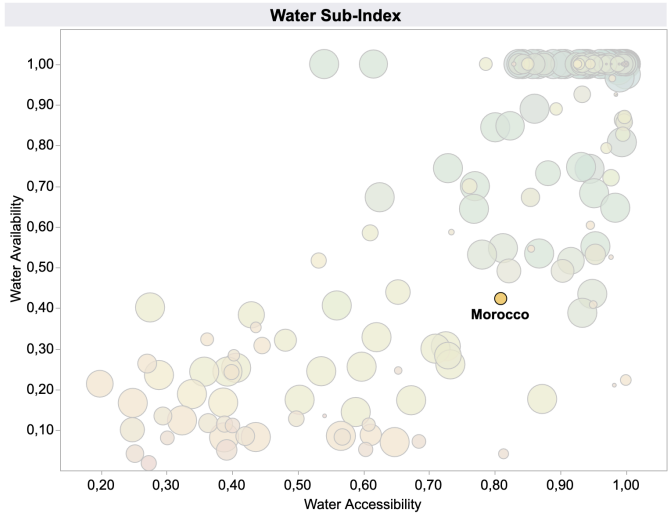
Table 9. Comparison of the FEW values of different geographical regions and countries

Regions	FEW value
MENA Region	0,54
Tunisia	0,55
Algeria	0,50
Sub-Saharan Africa[85]	0,37
EU-27	0,79
Spain	0,79

Source: Own compilation of data.

Through the below data visualization of the FEW Sub-Indexes in Morocco, one can get a clear picture of the country's current situation against the three Nexus resources; compared to the other countries in the world, which are also represented with circles in a lighter color. In Figure 25, the graph shows how Morocco scores in terms of Water availability versus its accessibility.

Figure 25. Water Sub-Index graphic



Source: https://www.prgs.edu/pardee-initiative/food-energy-water/about.html

[84] The particular indicators and data sources used in each sub-index to calculate the FEW Index can be found here: https://www.rand.org/pubs/tools/TL165.html, under the Appendix A.

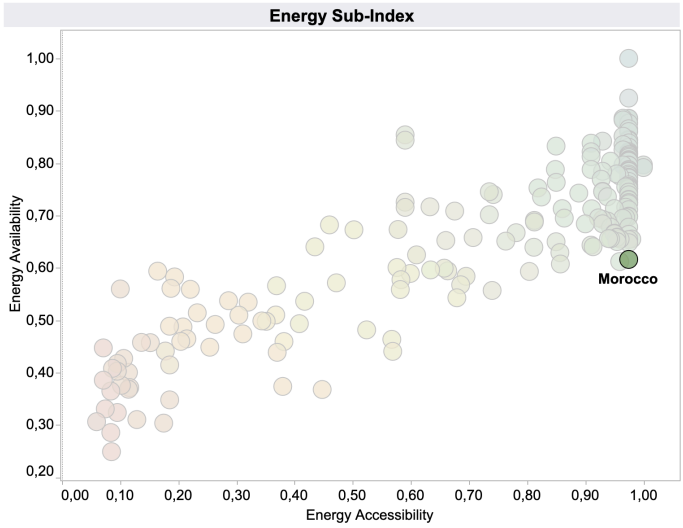
[85] The following Sub-Saharan countries and/or territories have not been included as there is no information available: Eritrea, Somalia, South Sudan, Democratic Republic of Congo and Western Sahara.

Water Accessibility = 0,81
Water Availability = 0,42
Water Adaptative Capacity = 0,17
WATER SUB-INDEX = 0,39

It is clear from the Figure 25 that Morocco has a very good Water Accessibility, thanks to the up to date and well deployed infrastructure that the country has built; whereas Water Availability appears to be rather deficient, namely due to climate change effects and the increased frequency of severe droughts. Moreover, the dramatic score on Adaptive Capacity emphasizes the urgent need to tackle climate change effects from an integrated approach.

In Figure 26, the same graph is performed for the Energy Sub-Index, showing the country's excellent Energy Accessibility -sector in which the GoM has put strong efforts, reaching a 100% rural energy access for instance. Whilst on the Energy Availability side, Morocco performs reasonably good, hindered by the country's persistent dependence on energy imports.

Figure 26. Energy Sub-Index graphic

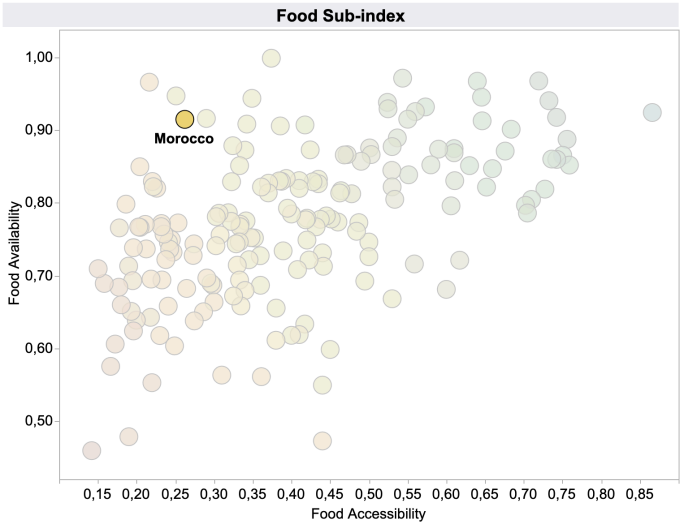


Source: https://www.prgs.edu/pardee-initiative/food-energy-water/about.html

Energy Accessibility = 0,97
Energy Availability = 0,62
ENERGY SUB-INDEX = 0,78

With regard to Food Sub-Index graphic in Figure 27, it is clear that the country has excellent food availability, however urgent work is needed in order to improve its accessibility, ensuring food is made equally accessible to people in the whole territory.

Figure 27. Food Sub-Index graphic



Source: https://www.prgs.edu/pardee-initiative/food-energy-water/about.html

Food Accessibility = 0,26
Food Availability = 0,91
FOOD SUB-INDEX = 0,49

Assessing the MENA Region

Table 10. Comparison of FEW Index throughout the MENA Region

Country	FEW Index	Country	FEW Index
Algeria	0,50	**Libya**	0,53
Egypt	0,56	**Morocco**	0,53
Iran	0,68	**Oman**	0,54
Iraq	0,65	**Saudi Arabia**	0,51
Israel	0,61	**Syria**	0,66
Jordan	0,47	**Tunisia**	0,55
Kuwait	0,39	**UAE**	0,45
Lebanon	0,68	**Yemen**	0,27

Source: Own compilation of data.

The FEW Index describes the security level of food, energy, and water at a national level. However, resource security is shared at both smaller and larger scales. Oftentimes, resource insecurity can span regions that cross national boundaries, for this reason the FEW Index has been performed throughout the MENA region[86], leading to the results shown in Figure 34.

[86] Some countries and territories belonging to the MENA Region are not included in this table due to the lack of publicly available information.

As shown in Table 10, there exist a wide variation among the FEW Indices of individual countries within the same region, spanning from the 0,27 of Yemen until the 0,68 of Lebanon and Iran, which hold the overall highest values of the region.

The majority of the countries in the MENA Region follow similar trends and have their indices around or above 0.5. Most countries of the region also share another pattern: water security results are the lowest and food security ones the highest. This showcases how the Middle East and North Africa region is severely affected by climate change, particularly stressing droughts and water shortages, leaving them in one of the most vulnerable climate situations worldwide.

5.3 Nexus sensitive polices and strategies

The GoM has already begun to recognize the complexity and importance of the Water-Energy-Food interlinkages in the elaboration of its public policies regarding water management, energy production and food security under the pressure of the increasing demand driven by population growth, urbanization and intensification of agricultural and industrial activities. Morocco has already approached the WEF Nexus in several ways and initiatives:

- The strategic institutional decision through the combining of the high-up administration. Morocco gathered the energy, water, and environmental policy Ministries, and combined them all within the same department, creating the Ministry of Energy, Mines, Water and Environment. This represented a major soft landing to the WEF Nexus; since all these institutions are now integrated, collaboration among policymakers from the WEF Nexus disciplines is enhanced, allowing for a more efficient and streamlined policy-making process. This consolidated Ministry makes policy decisions as a unit, and these decisions are making a positive change in respect to resource availability and management in Morocco.

- Another strategic institutional decision that was taken was the merger of the 2 public utilities, in charge of the electricity and drinkable water, into a single entity. The consolidation of institutions in both of these examples instigates more efficient and collaborative change when it comes to policymaking in the country.

- The development of an active coordination action with the Department of Agriculture through the generalization of drip irrigation and solar water pumping with PV, which are expected to have a sound impact on irrigation efficiency and water consumption.

- Besides the PNEEI's incentives to reduce water use and local irrigation in order to stabilize agricultural incomes, another strategy in place are wastewater treatment facilities. After the wastewater treatment, the water is ready to be used and pumped into the irrigation system. Such practices will help lowering water insecurity over the coming years.

As just outlined, there are numerous ways in which Morocco has already begun to implement coordination mechanisms in relation to existing planning processes in the Nexus. There are also some WEF Nexus related projects currently being implemented:

- The National Office for Electricity and Drinking Water in Morocco is investing $26.1 billion in electricity projects and $25,5 billion in water projects across Morocco for the 2019-2023 strategy. More than $8 billion will be invested in electricity production projects. The energy goals will have 4.240 MW of the power generated from solar, wind, and hydroelectric power (Eliason, 2019). Strategies include having improved irrigation techniques so less water is required in agriculture.

- The Ministry of Energy, Mines, Water and Environment has focused on a plan for investing 200 Million Euros for the development of solar panels in Morocco. The purpose of this plan is to educate and increase the use of solar energy to power water pumps for irrigation use. Butane gas is the main source of power that farmers use, which can be high priced, so increasing the number of solar sources allows more than just less pollution but it will help decrease the cost of irrigation allowing farmers to become flexible.

- The Ministry of Interior in Morocco has adopted a plan called *the urban water conservation pilot,* funded by the Harvard Kennedy School and conducted by Global Nexus, which focuses its efforts towards the efficiency of water use in cities. It includes incentives for the households, on their water bills, so that if you have been consuming water conservatively you get credit as recognition, making your bill even cheaper. The first phase turned out well with 30 households during six months, so they are currently doing this pilot again (Phase 2), reaching 500 households this time.

- The development of the Agadir desalination project is another example of how resources are put into existing Nexus related initiatives already underway in Morocco. This project uses the energy created from the Noor Complex to power the Agadir desalination plant. As a result, instead of having to rely exclusively on unpredictable rain patterns, Morocco can draw power from an already established renewable source. This desalination plant strives to run off exclusively from solar energy. This, in turn, is suppling its residents with a reliable source of fresh drinking water.

5.4 Persisting challenges and weaknesses

In a study on *Climate Change Vulnerability and Adaptation in North Africa*[87], Schilling et al. argue that among all countries in North Africa, "Climate change will likely have the strongest effect on Morocco". Moreover, it states that "Morocco is highly vulnerable to the impact of climate change, particularly with regard to its water resources, and in coastal and desert regions" (Grant, 2011).

Thereby, the impacts that climate change has and will have on Morocco are broad and sever: sea-level rise and coastal erosion, an increase of the average temperature and the change in precipitation patterns, leading to drought and desertification, are among the most quoted effects. But also extreme weather events, such as storms and flooding, are becoming more and more common. Earthquakes add up to the hazards that Morocco is increasingly suffering from. Overall, Morocco is struggling to achieve an ambitious development agenda without compromising natural resources and the environment.

Sea-level rise
In Morocco, most of the population lives along the coast, and 80% of the urban population lives in coastal cities (mainly Rabat and Casablanca). The Intergovernmental Panel on Climate Change[88] (IPCC) expects the sea-level rise to affect Moroccan urban areas by 0,1m by 2030; 0,17m by 2050 and even higher levels over the next 50 years (Grant, 2011). This will most likely increase the cities' vulnerability to flooding and storm surges. Casablanca has already experienced urban flooding and the combination of sea-level rise plus precipitation make the city's coastline especially vulnerable; around 50km of coast along the city of Casablanca are said to be at direct risk of erosion (Grant, 2011).

Temperature rise
In the past years, North Africa has experienced an overall rise in temperatures. These observations are especially true for Morocco, and are attributed by the IPCC to climate change (IPCC, 2014:7). The worst part is, that the trend is expected to continue: the medium temperature in Morocco is expected to rise by about 1.1°C to 3.5°C by 2060. However, it will not occur at the same pace in all regions of the country. On the coast it will be slower than in the interior regions, where the rise will be faster (World Bank, 2016d).

Precipitation pattern variability
At the same time, precipitation is expected to decrease in North Africa by 10-20% in 2050 (Schilling et al., 2012:1), while other studies predict up to a 30% decrease in particular regions (Schilling et al., 2012:5). Since the 70s, the average annual rainfall in Morocco has decreased year after year. The variability in precipitation

[87] See: https://www.sciencedirect.com/science/article/abs/pii/S0167880912001648
[88] IPCC: Intergovernmental Panel on Climate Change (IPCC), is an intergovernmental body of the United Nations that is dedicated to providing the world with objective, scientific information relevant to understanding the scientific basis of the risk of human-induced climate change, its natural, political, and economic impacts and risks, and possible response options.

patterns also brings a higher chance of extreme weather events for the entire North African region, leading for instance, to flash floods (Schilling et al., 2012:7).

Drought

According to the World Bank, drought is the number one natural disaster on the list, in terms of number of people affected and economic losses that Morocco experiences (World Bank, 2016d). "Drought frequency and intensity have increased in recent decades and are projected to worsen with climate change". The Atlas play a crucial role in that, given that climate change effects there also have implications for the lowlands: the reduced snowpack in the Atlas leads to a rapid springtime melting and an overall reduction in the available seasonal water resources in the lowland areas of Morocco (IPCC 2014 & IOM 2016).

Groundwater scarcity

The lack of effective mechanisms to manage aquifers[89] is leading to a greater overexploitation of groundwater resources, consequently compromising longer-term sustainability. As of today, most wells used for irrigation are not registered or counted, there does not exist an inventory but instead they remain unregistered. Morocco has already experienced the dramatic consequences of aquifer depletion on agriculture and the local economy[90]. In addition, according to the IPCC's projections, Morocco's groundwater reservoirs are expected to go through a salinization process due to the increased pumping of groundwater, which leads to saltwater intrusion. This process is expected to increase in line with the intensification of irrigated agriculture.

The challenge here is to change the current model where each groundwater user tries to get the most water for short-term profit, into a model where farmers jointly plan their consumption and adapt their productions and crops accordingly. The GoM is currently focused on creating a new type of contracts for groundwater management, hoping that they will collectively benefit it in the long run (World Bank, 2015).

The way forward will be to persuade farmers to get into the groundwater management contract as well as to establish local governance and self-enforcement mechanisms in order to make sure users respect their obligations. In this new generation of contracts, it will be essential to guarantee that small and vulnerable farmers also have a say in the design and implementation of the contract.

These actions call for better enforcement of water laws and regulations, particularly regarding well digging and irrigation water use. This could accompany improved water resource management in rural areas. International experience indicates effective water resource management addresses short and long-term water scarcity problems (M. Hssaisoune, 2020).

[89] Groundwater governance is difficult to monitor and enforce. In Morocco, despite the provisions of water law No.10-95, which imposes that all water users must register their wells, apply for an abstraction authorization, and pay the volumetric fee for groundwater abstraction, in practice it has proven extremely challenging for river basin agencies to ensure compliance. Global experience teaches that attempts to control groundwater abstraction through coercive actions have often failed (World Bank, 2015).

[90] In Guerdane, 13.000 ha of crops dried before the irrigation Private Public Partnership (PPP) was established. The available water resources enabled irrigation of only 10.000 ha, leaving 3.000 ha aside.

Desertification and Land Degradation
The IPCC highlights that Morocco is experiencing fast forest degradation due to climate change, particularly in the western Sahel area as well as in the semi-arid zones of Morocco[91]. The degradation of oasis is mostly due to droughts and extreme weather events, which challenge the traditional methods of agriculture. In addition, the increase in population brings the agricultural land to an overuse, also resulting in an increase of groundwater consumption (IOM, 2016).

Immigration and emigration
As a migratory and climate-vulnerable country, Morocco is particularly concerned with climate migration. Environmental events are responsible for migration to Morocco from sub-Saharan Africa, especially to the major coastal cities. In addition, they also increase the pressure on natural resources in most rural areas. With the impacts of climate change expected to rise in intensity in the coming years, migration movements are expected to intensify (IOM, 2016[92]).
Until very recently, Morocco was perceived as a country of emigration, a sending state with a large workforce abroad that contributes to the development of the country through remittances. In recent years, however, the country's role as a transit location for those aiming to reach Europe has resulted in many migrants staying in Morocco. This change is slowly being accepted by researchers and policymakers alike who analyze and react to this shift and possible "migration transition" (de Haas, 2005), "even if the collective consciousness has not yet incorporated these facts" (CNDH, 2013).
Although emigration still dominates the picture, Morocco's importance as a country of transit and destination for migrants from sub-Saharan countries has slowly increased over the past years. That puts indeed extra pressure on the management of water, energy and food resources, in a sustainable way.

5.5 Harnessing Opportunities

However, these high-stakes challenges create opportunities for innovative solutions. Some of the latest technological innovations and new research lines to face these aspects are listed below, classified under climate technology innovations -directly tackling energy, water and/or food; and, smart and sustainable cities -targeting solutions that intersect directly with the society and its behavior, mostly in urban areas:

Climate-smart solutions
The GoM, under the PMV, is already introducing climate-smart technologies to reduce the water use for irrigation, such as: direct seeding, climate-resilient varieties, and enhanced water management techniques. There are numerous innovations under development that could enhance the GoM's intentions once mature enough. Technology has allowed the development of products that can

[91] See: https://www.ipcc.ch/report/ar5/wg2/
[92] IOM (International Organization for Migration). 'Assessing the evidence: migration, environment and climate change in Morocco'.
https://publications.iom.int/system/files/pdf/assessing_the_evidence_morocco_en.pdf

substantially increase agricultural yields or provide financing to clients without guarantees, to name a few. It is important to tailor the instruments to the local conditions.

- **Smart tariffs.** Operating during the low fare hours when the demands for electricity are lower and the prices drop, for example during the night hours (Owen & Ward, 2010).

- **Net metering**[93]. Feeding into the grid the excess electricity produced by decentralized renewable energy units combined with irrigation. This would enable farmers to get a quicker return of investment and an additional income stream.

- **Combined renewable energy and desalination units**. The deployment of desalination units through combined solar and wind energy devices (DOE, 2014; IRENA, 2015).

- **Second generation biofuels.** Emerging feedstock alternatives to food crops include woody crops, byproducts from agriculture and forestry, organic waste or lignocellulosic materials -second generation biofuels; micro algae and micro bacteria -third generation biofuels; and engineered plants with special characteristics and low input requirements -fourth generation biofuels. The processing of such feedstock is still at a demonstration stage and results expensive. Nonetheless, the IEA estimates that by 2050, 90% of the biofuel based GHG reductions may come from advanced biofuels (IEA & IRENA, 2013).

- **Efficient irrigation technologies.** Some of the trends to maximize water productivity and reduce water losses are through the use of GIS, water metering and efficient application for precise agriculture solutions as well as high efficiency systems like drip irrigation or sparkling (Foster, 2010).

- **Non-conventional water sources for irrigation**. Treated wastewater and grey water reuse for irrigation is becoming an upcoming trend, though also encountering considerable social acceptance barriers. Reuse of treated industrial water or even oil and gas produced water is also being considered, though in this case social opposition may result in absolute unworkability (DOE, 2014).

- **Water availability.** Research is being conducted on alternative water resources. As of now, the most advanced technologies are around desalination, water recycle, water reuse and rain-water harvesting.

- **Saline agriculture.** The use of saline water for agriculture, by shifting to salt-tolerant crops. Some techniques used to develop salt-tolerant crops include selection, hybridization, back crossing, tissue culture and genetic engineering (Lundqdvist, 2008).

[93] An example of a program facilitating this option can be found in Missouri, U.S.; where the Department of Natural Resources enacted a legislation requiring all electric utilities to offer net metering to customers with systems up to 100 kW (NAACP, 2014).

- **Resistant crops.** Creating seeds and crops that are resistant to water scarcity, insect plagues, higher temperatures and rainfall variability is being investigated using natural breeding and genetic engineering techniques (FAO, 2009).

- **Food conservation**. Conservation solutions, like using a low-temperature thermal source to dry the food, what can significantly reduce the energy used (IRENA, 2015).

- **Sharing economy.** To tackle the impossibility of buying machinery that is very expensive, especially tractors, new Apps have emerged in rural areas of Nigeria, Kenya, Senegal, Tanzania or Mozambique, which allow small rural farmers to rent tractors, via mobile phone, so they can improve their crop yields.

- **New food.** Alternative protein sources are already entering the market and starting to be socially accepted. They are meat replacements, manufactured from plant proteins, mycoproteins and algae (Bonny et al., 2015).

Smart and sustainable cities

The WEF Nexus represents a complex and transversal sustainable development challenge that intersects with many other disciplines such as housing, rural migration to urban areas, new transportation modalities, population growth and population ageing, new consumption patterns, IoT solutions, etc. Cities have a key role to play in addressing the complex sustainable development challenges that our society is facing. Some of these new trends are highlighted below:

- **Resource efficiency and cleaner production.** Attaining a circular economy model, closing up the resource cycle; reducing waste, conserving the resources along the supply chain, recycling and reusing materials, rethinking lifecycles from the design phase, etc.

- **Urban agriculture**. Creating urban farms is a considerably wide-spread trend in developing economies and has also extended to developed countries as an alternative to increase food security of urban low-income households (FAO & World Bank, 2008).

- **Food waste reduction.** Guarantying resource efficiency throughout the supply chain and a sustainable consumption. Food loss takes place at different moments: in the field due to failures crop, during storage or transportation due to deficient conservation or during the industrial processing due to restrictive selection and chain inefficiencies; and, at the distribution and consumer level due to non-unified quality regulations, misleading expiration date labels and poor awareness (Bagherzadeh et al., 2014).

- **Data collection and processing.** Real time monitoring systems as well as tools for data processing are needed to generate more precise data (DOE, 2014). Pilot projects with applied research are required to advance the deployment of new technologies into the market.

- **Smart buildings**. Technological innovations for buildings aimed to reduce resource use and waste generation including smart metering systems, decentralized energy production (green buildings, solar panels, geothermal heating) or smart controllable heating and cooling (independent heating, heat exchange pipelines), among others (Vattano, 2014; Hoff, 2011).

- **Women empowerment**. Women act like a catalyzer for social change with regard to consumption patterns. Women are the main household managers, and therefore youth will shape the behavior patterns of future generations (UNW-DPAC, 2015a). Having women involved in societal, resource management and decision-making structures is key to achieve a sustainable development.

- **Access to information and social awareness.** Society being informed and aware of the need for change towards a more sustainable consumption pattern is crucial to stop the increasing resource demand, thus reducing WEF Nexus pressures. Meanwhile, access to information for civil society is still limited though efforts towards higher transparency and corporate stewardship are emerging, especially within the private sector (UNW-DPAC, 2015a). Eco-labelling, carbon footprint certification and CSR measures proof to be effective tools to reach consumers and contribute to increase public awareness on the importance of these resources (Lundqvist, 2008).

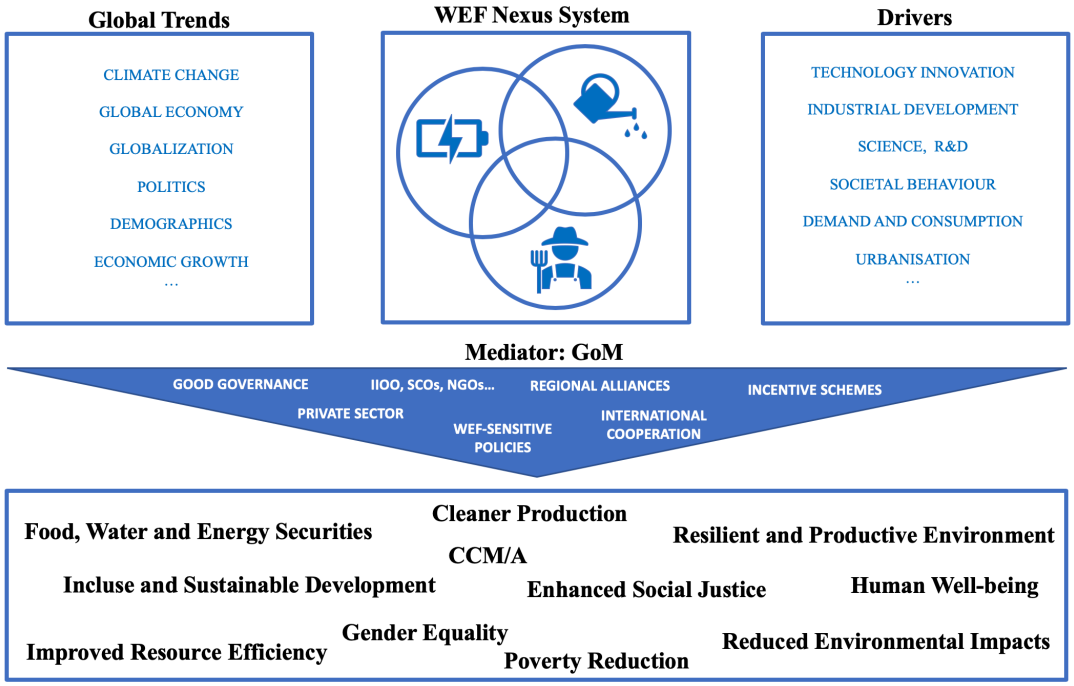
Chapter 6: Policy Recommendations for Morocco

6. 1 The need for an integrated WEF Nexus approach

By implementing a WEF Nexus model, Morocco can combat the severe environmental impacts the country faces while setting up for a more sustainable future.

Using a coordinated WEF Nexus approach is basic to effectively manage climate change pressures on Morocco's natural resources, as it is described in Figure 28 below. Without a sound policy management at the WEF Nexus, Morocco will confront challenges in sourcing enough water, energy and food to meet its domestic demand.

Figure 28. Integrated WEF Nexus approach



Source: Own creation.

Interventions need to contemplate actions at the national and local levels, be inclusive and consultative, and both bottom-up and top-down. Due to the local nature of water and agriculture: stakeholder consultation, ownership and cooperation with the local government will be crucial for a successful implementation. Needless to say, the selected approaches need to be suitable for local water, energy and agriculture policies, whilst strengthening them (FAO, 2018).

Moving forward, the WEF nexus provides an effective approach for government, industry, and academia to build natural resource resilience to climate change in Morocco and across the Middle East and North Africa.

The following section of this Thesis outlines how Morocco can successfully implement and manage the Nexus by giving practical recommendations to the effective mainstreaming of the WEF Nexus into national policies. For each of the three resources, a number of possible policy interventions are suggested, together with some cross-sectorial actions.

6.2 Methodology applied

The methodology used in this Chapter follows a step-by-step approach, to identify which practices should be prioritized based on the Nexus interdependencies (where the use of one resource conditions the availability of the other) under the Moroccan conditions, and their climate change mitigation and adaptation potential. Moreover, this section also analyses the barriers to adoption and suggests mitigation actions to ensure its implementation.

The overarching goal of this section is examining the question**: "***Where, as a country, does Morocco stand today in terms of efficiency and sustainability of the WEF Nexus management and what is the scope for further improving efficiency and sustainability through improved policies, investments, approaches and practices?".* A methodological approach has been developed in order to address this question; designed in four different steps:

- **Step 1-** Which are the most relevant practices in terms of preserving the availability of a given resource taking into account the WEF Nexus interlinks and interdependencies?
- **Step 2-** How can sectorial activities be promoted and incentivized based on sustainability principles?
- **Step 3-** Which of them present a higher potential in terms of climate change mitigation and adaptation that needs to be considered when selecting and advocating for these practices and activities?
- **Step 4-** Which are the main barriers to adoption and what mitigation actions could be undertaken to address them?

In addition, three relevant points have also been applied transversally with regards to: sustainability considerations, economic feasibility; and technical parameters.

So as to evaluate all these criteria in an operative manner, illustrative tables have been created for each sector (water, energy and food) plus a fourth one, with cross-sectorial recommendations.

- The first table analyses and suggests Policy Recommendations for each sector. It includes an overview of the current situation in Morocco and its legislative framework or policy gaps, followed by a description of the proposed regulation and its expected results. In addition, two quantitative

scales have been developed to inform on the cost (public expenditure) of each policy recommendation, being: €€€ very high, €€ medium, and € a low cost of adoption). Same is done to inform on the intensity of the proposed policy reform, being: *** very high, ** medium, and * low intensity policy reform.

- The second table focuses on evaluating the barriers that may hinder the adoption of the recommendations proposed in the previous table. The potential barriers are classified by its nature among: information availability, organizational, social acceptance, institutional or regulation, support services or infrastructures, financial returns, access to capital or cost. Then, its risk is rated between high, medium, or low. Finally, some risk-mitigation measures are proposed.

In order to obtain relevant information for the 4 steps of the proposed methodology, both quantitative and qualitative data was used. Whilst the quantitative data and its methodology has been broadly captured in Chapter 5; on the qualitative side, substantial contributions stemmed from Expert Interviews.

Expert Interviews

The interviews were semi-structured in order to gather and obtain as much expert knowledge as possible in the most structured and operational format for the purpose of this Thesis. The format adopted consists of open questions posed to the interviewees, giving them space to extend their answer. This format provided the following advantages:

- Interviews bring the opportunity to gather rich qualitative data;
- The natural language use by participants was considered essential in gaining insight into their perceptions and values;
- The interview format leaves room to the interviewee to bring up relevant issues that had not been considered, easing the recognition of potential key aspects not initially considered.

The interviews were structured in 2 different sections:

- The first one aims at dimensioning the WEF Nexus in Morocco, getting insider information on the three Nexus resources and their interlinkages. It also includes a series of open questions analyzing key innovations in the field in order to get the full picture of the domestic state-of-the-art. This section also leaves room for additional comments from the interviewees, to guide the conversation.
- In the second section, specific questions on the Nexus interactions were formulated, complemented by an assessment of its weakest points and barriers to adoption; paying attention to details for each of the targeted resources.

With regard to the interviewees, the experts were selected in order to have representatives from all the different stakeholder groups; when possible they were made face-to-face and, when it was geographically challenging, meetings were conducted through video calls. The template that was used to guide the interviews can be found in Annex I -both its English and French versions. The list of the local and international experts interviewed, the stakeholder group they belong to and their current position are listed under Annex II. The results and conclusions from these interviews have been used to guide the development of the policy recommendations proposed in this section.

Figure 29. Expert Interview with researchers at the Université Abdelmalek Essaadi, Morocco

Source: Field trip photo. Morocco, June 2019.

Data availability

When interpreting the results derived from this methodology, it should be noted that a mixture of data sources has been used due to the lack of data availability in many sectors of the country. Particularly, data has a variable coverage among the territory and its quality is not always homogeneous among the different sectors and subsectors, etc.

For the purpose of this research study, official data from the different ministries was used, complemented with international organizations data (mainly the World Bank and FAO), along with industry sources, NGOs, civil society organizations and academia. The results of these sections are therefore dependent on the quality of such sources and the availability of data.

On the basis of this thorough analysis, conclusions are drawn about key sustainable climate practices for the Moroccan water, energy and agro-food sectors in order to guarantee an appropriate WEF Nexus management that will help tackle the effects of climate change.

6.3 Policy Recommendations and Barriers to Adoption Analysis

Table 11. Water recommendations to tackle climate change through a WEF Nexus management.

Water Recommendations to tackle climate change through a WEF Nexus management

#	POLICY	Expected Result / Further Information	Current regulation / Policy Gap	Proposed Regulation	Cost / Public Expenditure	Policy Reform Intensity
W.1	Improvement in water management	Need to induce stakeholders to improve water use efficiency. Numerous institutions (including basin authorities, irrigation schemes, water utilities, environmental agencies, etc.) are directly involved in the management of water resources but with limited mechanisms and incentives (including water tenure and tariffs) to induce stakeholders to improve water use efficiency.	The country's commitment to an integrated water resource management approach is reflected in: - National Water Strategy (SNE, 2009). - National Water Plan (PNE). - New Water Law 36-15 (2016). The SNE and PNE aim at improving integrated water resources management, developing unconventional water resources, preservation methods, the protection against pollution, training, R&D and awareness raising around these topics. In addition, the NDC puts emphasis on the SNE and PNE, recognizing that water resources are the most constraining factor for sustainable economic and social development. The Water Law 36-15, provides the relevant policies, institutions, regulations mechanisms and procedures for integrated water resources management. It recognizes the need for integrated, decentralized and participative management of water; while recognizing the importance of developing planning mechanisms to address water scarcity.	Empower the different water institutions involved in the management of water resources with capacity to promote efficiency in the water use, through tariffs, bonuses and incentives schemes.	€€	**
W.2	Tackling groundwater depletion	Groundwater is coming under increasing pressure in response to climate variability. Policies governing water across sectors need therefore to be better adapted in order to optimize the use of scarce water resources. Future development pathways need to promote more consistent groundwater governance that enhances productivity, equitable access and sustainable quantity and quality of groundwater resources. Revert the innefficient management of groundwater resources, specially through a strong compliance of the current legislation. Improve the efficiency and profitability of groundwater use and use a participatory approach to modify the incentive structure may contribute to reduce groundwater depletion.	Due to the invisibility of the resource, groundwater governance is exceptionally difficult to reform. The main regulations regarding groundwater include the following: - National Water Strategy (SNE, 2009). - National Water Plan (PNE). - New Water Law 36-15 (2016). - PNEII.	Create a regulation that enables farmers to sell back to the grid their unused renewable energy.	€€	***
W.3	Improving water quality	Although Morocco is catching up to other middle-income countries with respect to industrial and household wastewater treatement, a significant amount of untreated effluent is resturned directly into wadis or percolates into aquifers with direct risks to human health and the environment.	Inadequate maintenance of water distribution and sanitation networks. Improvements can be done in the water production systems for urban areas and increased acces by rural communities to water supply.	Strengthen and secure access to drinking water supply at 100% in both urban and rural areas.	€	**
W.4	Deployment of new 'Water-Nexus' solutions and Investment Promotion	Accelerate the development and innovation on water technologies and solutions. Promote the deployment of new technology solutions such as desalination plants like the Agadir project, coupled with the use of renewable energy.	Scarcity forces farmers to pump more groundwater to irrigate crops and fruit trees. Farmers are well aware that climate change is happening so groundwater pumping is a short-term adaption measure. However, pumping only exacerbates water shortages. The GoM is already taking steps to promote the adoption of new techological solutions, for instance: it has implemented a water pumping policy that encourages farmers to use uniquely solar energy. Such actions call for better enforcement of water laws and regulations from a Water-Nexus perspective, particularly regarding well digging and irrigation water use for the short and long-term.	Conduct awareness raising campaigns, together with pilot programmes to proof benefits.	€	*

Table 12. Water Barriers to adoption

Water Barriers to Adoption (being * low , ** medium; and * a high barrier to adoption)**

POLICY	Information availability	Organizational	Social Acceptance	Institutional /Regulation	Support services/ Infrastr.	Financial Returns	Cost/ Access to Capital	Risk Rating	Risk Mitigation measures
Improvement in water management	**	***	*	***	**	**	*	*High*	Setting tariffs, bonuses and incentives will promote a better efficiency in the use of water.
Tackling groundwater depletion	***	***	*	***	**	**	***	*High*	Rise awareness through intensive campaigns as the main couse of depletion is the invisibility of the resource.
Improving water quality	**	*	*	**	**	*	*	*Low*	Secure access to drinking water in rural areas by designating it a national priority (also aligned with the A2030).
Deployment of new 'Water-Nexus' solutions and Investment Promotion	**	*	*	*	*	*	**	*Low*	Promote Nexus solutions among the involved stakeholders, granting a homogeneous dissemination throughout the country.

Source: Own creation.

Table 13. Energy recommendations to tackle climate change through a WEF Nexus management

Energy Recommendations to tackle climate change through a WEF Nexus management

#	POLICY	Further Information and Expected Result	Current regulation / Policy Gap	Proposed Regulation	Cost / Public Expenditure	Policy Reform Intensity
E.1	Foster the clean energy transition	Keep investing in and promoting RE to further diversify the country's energy mix. Fully opertationalize ANRE, the National regulatory Authority created in 2018, extend its mandate and ensure its staff have both the skills an political support to ensure the creation of a competitive and well-functioning electricity sector. Complete the electricity and gas market reforms.	Ambitious targets are already set and are driving sector development, namely the ones stated in the Energy Strategy 2009 and Morocco's NDC. The GoM is already changing its future mix by developing renewable energy technologies and has set ambitious targets for 2030.	Building upon the existing Energy Regulation of 2009, develop further energy sector plans and policies to achieve the ambitious targets of Moroccos' NDC (particularly on RE). Empower ANRE to have access to all networks through cost-reflective tariffs, both at transmission and distribution levels, and by overseeing the whole value chian in the electricity sector. In addition, extend ANRE's mandate to cover the natural gas sector.	€€€	***
E.2	Strengthen energy efficiency	Implement and operationalize the existing energy efficiency regulations. Notably the Energy Efficiency Strategy 2030 supported by the consequent financial resources to implement it. Adopt cost-effective Energy Efficiency (EE) polices and standards for key sectors, ie. streetlightning, industry, households, mobility sector, etc.	Weakness in the legislation and regulatory instruments for EE (a detailed energy efficiency framework was adopted in 2011 -Law 47-09. But its implementation was challenged by the lack of coordination within the government and the lack of the needed financial resources). Upcoming Energy Efficiency Strategy for 2030 (the GoM created it in order to achieve its ambitious 2030 targets, and is currently under consultation with the stakeholders involved).	Impose EE measures in key sectors (the ones with an emission potential > 1.800k tonnes of CO2eq avoided). Financial support to implement the EE Strategy in the different sectors. Development of incentive schemes to stimulate the demand side. Develop capacities locally in order to take full advantage of the EE potential throughout the whole supply chain.	€€€	***
E.3	Improve Morocco's energy security	Carefuly manage the risks and develop alternative plans to the dependence on energy imports (particularly oil). Take steps towards securing future natural gas imports and strengthening the operation and planning of the power system, preparing it for the integration of a higher penetration of RE.	Almost 91% of the energy used in Morocco is imported, including: oil, petroleum products and coal from international markets, gas from Algeria and electricity from Spain. The only traditional domestic energy sources of Morocco are: biofuels, waste energy and hydroelectricity, which represent a very small % of the domestic electricity supply. Morocco relies mostly on fossil fuels to meet its domestic energy demand (oil representing around 2/3 of the total).	Gradually reduce its oil dependency, through the transition to natural gas and further deployment of renewable energy systems throughout the country. Adopt a comprehensive long-term approach with measures on both supply and demand sides equally, with the aim to foster energy security. Available funding and economic incentives that support this shift. Facilitate access to credit for renewable energy users.	€€€	***
E.4	Deployment of new 'Energy-Nexus' solutions and Investment Promotion	Accelerate the development and innovation on renewable energy technologies beyond the power sector. For instance: sustainable heating and cooling solutions or new water management techniques. Promote the deployment of new technology solutions such as desalination plants which are very energy intesive.	The GoM is already taking steps to promote the adoption of new techological solutions, for instance: it has implemented a water pumping policy that encourages farmers to use uniquely solar energy. However, the goals for the sector could entail broader renewable energy targets.	Offer grants for renewable energy water pumping and reduce/revise butane subsidies. Create a regulation that enables farmers to sell back to the grid their unused renewable energy. Conduct awareness raising campaigns (the support and involvement of ONEE, as a Nexus agency, will be instrumental).	€€	**

Table 14. Energy Barriers to adoption

Energy Barriers to Adoption (being * low , ** medium; and * a high barrier to adoption)**

	POLICY	Information availability	Organizational	Social Acceptance	Institutional /Regulation	Support services/ Infrastr.	Financial Returns	Cost/ Access to Capital	Risk Rating	Risk Mitigation measures
E.1	Foster the clean energy transition	*	**	*	**	***	*	**	*Low*	Priority should be given to the operationalization of ANRE in order to trigger the full energy transition.
E.2	Strengthen energy efficiency	*	***	*	***	**	*	***	*Medium*	A Steering Committe should be put in place in order to guarantee the coordination needed within the government as well as the mobilization of the financial resources to implement it.
E.3	Improve Morocco's energy security	*	*	*	*	**	*	***	*Medium*	Consolidate the use of natural gas as a transition fuel and secure it.
E.4	Deployment of new 'Energy-Nexus' solutions and Investment Promotion	**	*	*	*	*	*	***	*Low*	Make sure smallholders: (a) Get to know such innovations through awareness raising campaigns and capacity building programmes; and (b) Benefit from them; grants and subsidies will facilitate dealing with high upfront costs.

Source: Own creation.

Table 15. Agro-Food recommendations to tackle climate change through a WEF Nexus management.

Agro-Food Recommendations to tackle climate change through a WEF Nexus management

#	POLICY	Further Information and Expected Result	Current regulation / Policy Gap	Proposed Regulation	Cost / Public Expenditure	Policy Reform Intensity
A.1	**Climate-Smart agriculture deployment**	Introducing technology and innovation into smallholder systems as a strategy to increase productivity and efficiency.	PMV - Plan Maroc Vert Most producers are smallholder farmers who lack access to high-quality certified seeds, fertilizer, machinery, climate information, market access and financial services; all of which limit their ability to increase their yields and income.	Grant access through subsidies to an efficient use of fertilizers to smallholder farmers in order to replenish soils and boost production. Also increase the subsidies to cover up-front investments. Create pilot programmes with lead farmers to illustrate the benefits. Prescribe cost-effective and user-friendly technologies to farmers, which can demonstrate solid impact on profitability without interfering with other practices. Provide Train-the-Trainer programmes to farmers in order to develop their capacities.	€€€	***
A.2	**Investment promotion and attraction**	Mobilizing private sector involvement in smallholder value chains would open the opportunity to generate sources of revenue and contribute to scaling out climate smart agriculture in the country.	PMV - Plan Maroc Vert The use of climate information has become integral to farmers' decision-making and farming practices. However, access to finance is limited for smallholder farmers and represents a significant barrier to adopting climate smart agriculture practices.	Increase incentives for private investment. Invest in R&D and innovation.	€€€	**
A.3	**Adaptation pathways to climate variability**	The GoM should continue implementing measures to address climate variability while performing a thorough agricultural and meteorological monitoring. Raise agricultural incomes thorugh enhanced productivty. For instance by focusing on tree crops, like citrus and olives, which are more climate-resilient than field crops.	PMV - Plan Maroc Vert Addressing the adverse effects of climate variability is one of the main challenges for agriculture in Morocco. More can be done, especially for the strategically important subsectors of Morocco.	Drive a shift towards tree crops (especially olives and citrus) and potentially expand subsidies. Creation of a multi-risk citrus and olive insurance (deemed strategic for the country).	€€€	*
A.4	**Deployment of new 'Agro-Nexus' solutions and Investment Promotion**	Promote the deployment of new technology solutions such as efficient irrigation technologies and practices through the use of GIS and efficient application for precise agriculture solutions as well as high efficiency systems like drip irrigation or sparkling.	PMV - Plan Maroc Vert	Subsidize the upfront costs of precise agriculture solutions. Build capacity among the most vulnerable farmholders in order to ensure no-one is left behind.	€€	**

Table 16. Agro-food Barriers to adoption

Agro-Food Barriers to Adoption (being * low , ** medium; and * a high barrier to adoption)**

	POLICY	Information availability	Organizational	Social Acceptance	Institutional /Regulation	Support services/ Infrastr.	Financial Returns	Cost/ Access to Capital	Risk Rating	Risk Mitigation measures
A.1	Climate Smart agriculture deployment	***	*	*	*	**	*	**	*Low*	Ensure a democratized and territorially homogeneous deployment of climate smart tecniques and financial aids through capacity building courses to farmer unions and awareness raising campaings throughout the country.
A.2	Investment promotion and attraction	*	*	*	*	*	***	***	*Medium*	It is crucial to create good incentive schemes to ensure the involvement of the private sector in smallholder value chains.
A.3	Adaptation pathways to climate variability	***	*	*	***	***	***	*	*High*	Drive a shift towards climate resilient crops so agriculture can resist the adverse effects of climate variability.
A.4	Deployment of new 'Agro-Nexus' solutions and Investment Promotion	**	*	*	*	*	*	**	*Low*	Top-down approach to disseminate the benefits of Nexus techniques.

Source: Own creation

Table 17. Cross-sectoral recommendations to tackle climate change through a WEF management.

Cross-Sectoral Recommendations to tackle climate change through a WEF Nexus management

#	POLICY	Further Information and Expected Result	Current regulation / Policy Gap	Proposed Regulation	Cost / Public Expenditure	Policy Reform Intensity
T.1	Good governance	Expand the information base and ensure the information is transversal, reliable and transparent among the different bodies. Ensure an effective coordination of actions and plans across different Ministries, relevant agencies and authorities. Increased Ministry collaboration will help strengthen the country's overall WEF Nexus preparedness. Ensure an effective prioritisation of the most important actions to be implemented in order to achieve the GoM commitments. Identify the most cost-effective solutions and invest in innovative practices and policies.	Lack of a reliable and consolidated information base. The existing information is fragmented and uncompiled. Need for a better inter-ministerial coordination. New technology applications make these information available to the range of stakeholders, but there's the need to organize and homogenize it at the country level, making sure it is reliable and accessible to everyone; in order to allow good decision-making.	Consolidation, extension and operationalization of the information base on water, energy, food and climate related systems. Capacity building trainings for all public officers among the different institutions in order to ensure they have all the tools needed for appropiate coordination and information sharing. Strong focus on the implementation strategy with clear points on priorization, cost-effectiveness and promotion to attract more private sector investment to boost economic development and lead to quality job creation.	€	**
T.2	Development of a National Nexus Policy (NNP)	By developing and implementing a WEF Nexus National Policy (NNP) 2020-2030, Morocco could combat the severe environmental threats while setting up for a more sustainable future. Moving forward, the WEF Nexus provides an effective approach for government, industry, and academia to build natural resource resilience to climate change in Morocco and across the MENA region.	As described in Chapter 5, Morocco is already actively utilizing insights from the WEF Nexus to craft solutions at both the sectorial and higher administration level.	Framework for the development of a National WEF Nexus Policy (NNP): 1. New Coordination Mechanism. 2. WEF Nexus monitoring. 3. Vulnerability assessment. 4. Mitigation and Adaptation responses. See further information under the section 6.4 of this Chapter.	€€	**
T.3	Investment promotion for innovative WEF Nexus solutions	The private sector is still insufficiently involved in the implementation of climate related solutions, namely on water, energy and food realted practices. The business environment in the WEF sector should be further improved.	Insufficient resource mobilization to ensure the adoption of new technologies and practices. It also needs to be noted that, not all technology innovations pay back due to their high initial investment costs, operation errors, malfunctions, inappropriate use, etc. The main obstacles to the adoption of innovative climate technologies are: - Access to credit / cost of capital. - Financial attractiveness. - Regulations and institutional issues.	Development of synergies through PPPs in the Nexus sectors, at the local level. Provide technical assistance (TA) and price incentives for business owners under Nexus sectors, committing the needed public expenditure. Ensure that an equal territorial support is provided throughout the country.	€	*
T.4	Building regional alliances and PPPs for enchanced climate resilience	Benefit from the creation of regional alliances along the MENA region and the Mediterranean countires. Some of the benefits of collective action and partnerships entail are: - Improved market efficiency. - Share the costs of public goods or large infrasturcture projects. - Decide policy cooperatively. - Have a building block for global integration. - Reap other non-economic benefits like stability and security.	Information sharing with neighbouring countries is far from being optimal. Enhancing such communications would allow to learn from the experiences and successes of others.	Consolidate the relation with other countries and create communication mechanisms, creating Regional Alliances for improved climate resilience. Such alliances should also be extended to the private sector, enabling the creation of public private partnerships (PPPs) to better tackle some climate development issues. Coalition building and experience sharing can enhance the impact and the efficiency of the already adopted measures.	€	**

Table 18. Cross-sectoral barriers to adoption

Cross-sectoral Barriers to Adoption (being * low , ** medium; and * a high barrier to adoption)**

	POLICY	Information availability	Organizational	Social Acceptance	Institutional /Regulation	Support services/ Infrastr.	Financial Returns	Cost/ Access to Capital	Risk Rating	Risk Mitigation measures
T.1	Good governance	***	***	*	***	**	*	*	*High*	Intraministerial coordination and information sharing needs to be ensured through the oversight of a higher body.
T.2	Development of a National Nexus Policy (NNP)	**	**	*	**	*	*	*	*Low*	The creation of a WEF Nexus Observatory will strengthen the collaboration and information sharing.
T.3	Investment promotion for innovative WEF Nexus solutions	**	*	*	*	*	*	***	*Medium*	Ensure funding streams to allow the adoption of innovative Nexus technologies.
T.4	Building regional alliances and PPPs for enchanced climate resilience	*	*	*	*	*	*	*	*Low*	Designate a person from each ministry involved (coordination team) to act as the focal point with the international community, so all the information is gathered and streamlined through them.

Source: Own creation

6.4 Framework for the development of a National WEF-Nexus Policy (NNP)

This section contains a framework for the development of a National WEF-Nexus Policy (NNP), as recommended in section 6.3 above.

The establishment of a WEF-Nexus Observatory, integrated by local and international experts is strongly recommended. Both groups of experts would work together in identifying sensitive WEF-Nexus scenarios and potential solutions. The local expert group should be integrated by representatives from the different ministries, national and local agencies (provinces and municipalities), think-tanks, academia, R&D labs and institutions. The international group of experts would provide overall guidance, insights from other countries' experiences and best practices. As a starting point, a scientifically rigorous WEF-Nexus set of indicators for Morocco should be developed; making sure it captures the state of the country when it comes to water, energy and food resources.

Having a strong institutional coordination mechanism as the Observatory would be instrumental for Morocco: it would act as single authority, being responsible to allocate resources, coordinate agency roles, and lead Nexus-related decision making. This could significantly improve information and knowledge-sharing among the different silos within the administration.

The Observatory would use accurate information on particular Nexus sensitive areas to predict the severity they might be exposed to as well as its duration, to initiate the development of WEF-Nexus management actions. Impact assessments could be undertaken at varying spatial scales, including at the provincial or river basin levels, and inform local WEF-Nexus action plans. It will be crucial to equip the Observatory with a budget in order to implement the different measures. The information generated would build preparedness and guide both sort and long-term strategic decisions.

The main tasks and expected results of the Observatory include:

- Development of WEF-Nexus impact assessments, as well as mitigation and adaptation responses.
- Integration of WEF-Nexus management plans with local and national development policies. This includes coping with short and long-term climate change adaption and mitigation measures.
- Development of emergency response plans based on a sound management of natural resources and self-help at appropriate governance levels.
- Analysis and design of new economic and financial instruments including; risk reduction, risk sharing, and risk transfer tools in WEF-Nexus management plans.

Below can be found a decalogue for a quick-start:

1. Appoint a national WEF-Nexus management policy committee, integrated within the Observatory structure.
2. Define the objectives of a risk and vulnerability based NNP.
3. Bridge the gap between the scientific and policy aspects for a sound Nexus management.
4. Seek stakeholder validation at all levels. The importance of stakeholder participation should be stressed throughout the whole framework.
5. Grant the inclusion of women, youth and other vulnerable groups.
6. Development of a National Nexus Policy, including: monitoring, forecast, early warning, risk and impact assessment, mitigation and adaptation responses.
7. Secure financial resources to grant the implementation of the NNP.
8. Public outreach: advocacy and awareness raising on the NNP.
9. Deliver capacity building programs for all age and stakeholder groups.
10. Constant monitoring and evaluation of the NNP for potential improvements.

Chapter 7: Further Work and Conclusions

7.1 Further Work

Whilst the research of this Thesis sheds light upon a number of aspects related to the water, energy and food nexus management in order to tackle climate change, it also touches upon various issues that deserve additional exploration. Without claiming to be absolute, this section outlines additional areas where further work would be desirable as a natural follow up to this dissertation.

7.1.1 New income stream

The water, energy, and food Nexus fosters income generation. Among the productive uses of informing policy-making and creating open and informative dialogue, the WEF Nexus generates income through job creation and by helping to guide investments.

Investment in the Nexus approach leads to quality job creation while providing solutions to face the environmental threatens. One example would be the jobs created in the renewable energy sector, to support the energy transition and to help pump ground water, for instance. The government plays a vital role in untapping the Nexus potential as a new income stream, and it will directly depend on its ability to speed up progress by funding or subsidizing innovative practices for the implementation of the Nexus policies.

Another way the water, energy, and food Nexus can generate income is by guiding investments. The Nexus is “an essential tool for sustainable investment” (The Broker) and it helps with options for joint investment decisions over shared resources as it provides an understanding of how the investment will impact different sectors and societies in the long-term.

7.1.2 Improving the information base

There is significant room to work further in a number of different fronts on measuring the WEF Nexus, but the first one is probably to improve the information base that can be relied on to manage and develop the WEF Nexus.

Therefore, to improve the information base, new tools should be used -if properly adapted to the micro level. This will allow researchers and policy-makers alike to

"full use of narrative-oriented and qualitative citizen data and to develop procedures and standards for quality controlling these data." (Lawford)

Satellites, geospatial information systems (GIS) and local data networks generate constant data that can be crossed with local measurements of stream-flow, soil moisture, etc. in order to get the full picture of the situation. Furthermore, in order to make the best and most educated decisions, big data must be made available in an open and transparent manner.

If data is made available, the methodology used in this Thesis could easily be applied to new context and scales; other countries, regions or smaller scales such as urban areas, local provinces, river basins, etc.

A good first step would be to perform a comprehensive inventory of the available information in a given country -or the selected geographical scale. This would bring clarity on data limitation, accessibility and comparability of the data; and would allow to work towards the harmonization of data and information. Sound statistical data is a prerequisite to effectively manage the WEF Nexus, evaluate the need for capacity development as well as knowledge gaps.

7.1.3 Geographical scale for implementation

Despite being at the forefront of the international agenda, the WEF Nexus has been proven difficult to implement. Being the geographical scale at which a Nexus intervention should be designed one of the greatest unknown factors, and the main barrier to implementation.

It is important that WEF approaches be considered not only on a national level but also on the local and regional levels, where minor changes can have major advantages.

But yet, the scale aspect remains to be a literature gap to be further elaborated upon. There is uncertainty regarding the best scale at which the WEF Nexus should be addressed. In the literature, a variety of arguments can be found ranging from the national level, to a sub-basin one, along with a cross-boundary regional approach.

7.1.4 Capturing the gender dimension

In the WEF Nexus, the gender issue is often left out of the analysis or treated very superficially. The lack of availability or accessibility to water, energy and food services bares a heavy toll on the poor, and disproportionately on women.

Gender perspectives are a major aspect of the Water, Energy, and Food Nexus. In fact, gender is considered by some to be the fourth aspect of the WEF Nexus, because of its importance in the conversation.

Change in policy must not only make water, energy, and food sectors more efficient, but they must prioritize the protection of women and girls. Women are the most vulnerable in resource crises, and therefore should be uplifted to positions of power and management throughout the implementation of a WEF Nexus strategy. The next step should be empowering women to take part in decision-making[94]. This is so critical because without women sitting in positions where their voices can be heard, nobody will listen to them.

There is the need to develop tools to guide governments on how to enable women to add to the conversation given that the current tools largely fail to capture the gender dimension. Indeed, available methodologies are helpful to evaluate access to water, energy and food from various perspectives. However, the access to them might not differ significantly between men and women. What is different are the impacts of the lack of access to modern water, energy and food services, whose burden mainly fall on women (Parikh 2011). Appropriate quantification tools are required to adequately capture and quantify the gender dimension in the context of WEF Nexus security.

7.1.5 Good governance for water, energy and food poverty

There seems to be global consensus on the difficult nature of the WEF Nexus issues, and the need to look at them in a less theoretical manner but a more practical, implementation-oriented one. This consensus should be used as an opportunity for global leadership.

The importance and difficulty of WEF Nexus policy does not allow for simple solutions, regulation, cooperation or governance. That's why WEF Nexus governance deserves additional attention from the global level to the most local one.

[94] i.e. Kenya is a country that is currently at the forefront of integrating gender equality into their policy developments. "*National policies acknowledge that if Kenya is to advance climate-resilient strategies in the areas related to water, energy, and food, consideration of gender is crucial, both from gender equality and operational effectiveness perspectives*." (CDKN, Climate and Development Knowledge Network). An example of this is that since 2010, their Constitution gives equal land rights to all people regardless of gender, court access, and freedom of movement. Furthermore, there is a call for representation of women in the document that reads "*no more than two-thirds of the members of representative bodies in each devolved government shall be of the same gender*" (CDKN).

7.1.6 Concrete reform proposals

In addition to the policy analysis and recommendations provided in Chapter 6, this exercise could be deepened in order to produce concrete reform proposals. This Thesis simply seeks to identify key policy areas and recommendations that can be explored further. However, moving from policy recommendations to actual reform proposals is a deep intensive process that needs to involve multiple stakeholders under the leadership of the government, and could perfectly be a natural follow-up to the results of the present research project.

7.1.7 Lessons learnt from past interventions

There is significantly increasing global attention on the Nexus. This is evident for instance in the recent prioritization of water, energy and food Nexus given by the Global Environmental Fund under its GEF-7 window, and the launch of various related multi-stakeholder partnerships. While the exact ongoing role of the international community is still being discussed and refined, there is a need to ensure robust analytical information is available to decision-makers.

Down this line, it would be valuable to examine the numerous ongoing and past activities at the national or local level aimed at expanding access to these three resources in developing countries to serve as precedent for future action. There exists a rich data set of policies, targets, regulations, and financial mechanisms. Assessing various interventions would allow presenting a set of best practices with specific insights for future policy design and implementation. It is essential to build upon the lessons learnt to ensure that the international community efforts are well aligned with the national and local needs.

7.2 Overall Conclusion

In this Thesis, policy proposals are offered on how to better understand and manage the issue of WEF Nexus security. Several recommendations are presented together with critical assessments of particular instruments to address it, with the ultimate objective of providing relevant insights for policy makers and guide the development of appropriate tools and measures. This research has been influenced by various schools of thoughts, and its theoretical inspiration comes out from a broad spectrum of disciplines, from science for policy to ecological economics.

Overall, this Thesis makes a contribution to the field by presenting various perspectives on the complex, multidimensional relationship between water, energy and food. The policy analysis and recommendations stem from applied research as well as methodological development.

The conclusions of this Thesis argue that, by improving the governance on the WEF Nexus management, higher levels of security, stability and resilience could be achieved in Morocco. In North Africa, stability is a policy goal and a global public good. These resources can play a remarkable role in the greater social and political dynamics of the region. It is important to better understand such interlinks to make sure they do not add to vulnerability, but instead promote stability (FAO, 2018). In order to trigger all the Nexus potential, the recommendations presented under Chapter 6, would need to be introduced into Morocco's national policies as a cross-cutting issue, along with poverty reduction and climate change, to name a few.

The WEF Nexus is a catalyzing force for social and economic development such as poverty reduction, environmental sustainability, the creation of quality jobs, open borders to climate migrants, gaining respect for the rights of indigenous lands, women empowerment, rural development, and political change, among many others.

The Water, Energy and Food Nexus brings us a step closer from achieving social justice and a far more habitable planet.

Climate change can change us for the better.

Laia Barbarà

Barcelona, 2020

Annexes

Annex I. Expert Interview Guiding Questions (English and French versions)

Expert Interview (EN)

SECTION 1: General questions on the WEF Nexus in Morocco

Question 1: How do National Adaptation Plans (NAPs) and the National Determined Contribution (NDC) of Morocco reflect integrated management practices to address water, energy, and food security from a Nexus approach?

Question 2: Do you think all 3 Nexus resources have the same relevance or there's one that deserve more attention for the particular case of Morocco?

Question 3: In your opinion, which opportunities and trends deserve higher observation since they are expected to have a higher impact in the short run?

Question 4: From your perspective, which are the weakest points or main knowledge gaps with regard to the Nexus?

Question 5: What role is climate change playing with regard to the WEF Nexus in Morocco? What effects would you foresee due to climate change when it comes to the water, energy and food availability/security in the coming years?

Question 6: From a decision-making point of view, do you think enough measures are being taken? Is there a strong governance when it comes to Water, Energy and/or Food issues in Morocco? Who are the main players and what else would you expect from them?

Question 7: Which roles do NGOs and CSOs play in promoting integrated water-energy-food management practices? Which goal are they trying to pursue?

Question 8: Is there any technology innovation or breakthrough that you think could change the rules of the WEF Nexus as we know them today?

SECTION 2: Specific questions on the trade-offs of the WEF Nexus

Water < > Energy

- *Dominant trends and technologies? (see proposed topics below)*
- *Derived/Expected social impacts?*
- *Main barriers to adoption?*

Topics: ageing of energy and water infrastructure / biofuel production and land deal / high-efficiency and low water cooling systems / hydro-wind energy integration / new generation biofuels / hydraulic pumping energy storage (as a key element for the take-off of renewable energy) / coupled renewables-desalination plants (incl. new desalination tech. such as membranes) / integrated water-energy modeling / self-generation (ex: solar thermal, solar PV, wind, solar pumping) / water conservation systems / water reuse and recycling / infrastructure failures due to extreme weather events.

Energy < > Food

- *Dominant trends and technologies? (see proposed topics below)*
- *Derived/Expected social impacts?*
- *Main barriers to adoption?*

Topics: food production vulnerability due to climate change / energy efficiency in the food industry / vegetal proteins / sustainable supply chains / resource efficiency and clean consumption / sustainable food consumption and production / change in the customers' behavior / food waste management / energy for fertilizers, mechanization and irrigation.

Food < > Water

- *Dominant trends and technologies? (see proposed topics below)*
- *Derived/Expected social impacts?*
- *Main barriers to adoption?*

Topics: productivity of rain-fed irrigation, saline crops, wastewater reuse in irrigation, productivity gap in Morocco (room for productivity improvements) / aeroponic crops (rapid growth crops requiring little water and soil) as an alternative for traditional biofuels / crop intensification / urban agriculture / rapid growth plants / impact of water pollution on agriculture / capture of real time data

through GIS (remote sensing) / genetic engineering / adverse effects of irrigation / land degradation / impacts of large-scale dams or mining activities, food insecurity due to draught or water salinity.

Modèle d'entretien avec un expert (FR)

SECTION 1 : Questions générales sur le WEF Nexus au Maroc

Question 1 : Comment les plans d'adaptation nationaux (PAN) et la contribution déterminée au niveau national (CDN) *du Maroc reflètent-ils les pratiques de gestion intégrée visant à traiter les questions de l'eau, de l'énergie et de la sécurité alimentaire avec une approche holistique ?*

Question 2 : Pensez-vous que les 3 ressources Nexus ont la même pertinence ou y en a-t-il une qui mérite plus d'attention pour le cas particulier du Maroc ?

Question 3 : À votre avis, quelles opportunités et tendances méritent une observation plus approfondie en vue du fait qu'elles auront un impact plus élevé à court terme ?

Question 4 : De votre point de vue, quels sont les points les plus faibles ou les principales lacunes dans les connaissances du Nexus ?

Question 5 : Quel rôle joue le changement climatique en ce qui concerne le Nexus au Maroc ? Quels effets prévoyez-vous en raison du changement climatique en ce qui concerne la disponibilité / sécurité de l'eau, de l'énergie et des aliments dans les années à venir ?

Question 6 : Du point de vue décisionnel, pensez-vous que les mesures prises sont suffisantes ? Existe-t-il une gouvernance solide en matière d'eau, d'énergie et / ou d'alimentation au Maroc ? Quels sont les principaux acteurs et quoi d'autre attendriez-vous d'eux ?

Question 7 : Quels rôles jouent les ONG et les OSC dans la promotion des pratiques de gestion intégrée eau-énergie-alimentation ? Quel objectif essaient-ils de poursuivre ?

Question 8 : Y a-t-il une innovation technologique ou une percée qui, selon vous, pourrait changer les règles du Nexus telles que nous les connaissons aujourd'hui ?

SECTION 2 : Questions spécifiques sur les compromis du WEF Nexus

Eau <> Énergie

- *Tendances et technologies dominantes ? (Voir les sujets proposés ci-dessous)*
- *Impacts sociaux dérivés / attendus ?*
- *Principaux obstacles à l'adoption ?*

Thèmes: vieillissement des infrastructures énergétiques et hydrauliques / production de biocarburants et entente foncière) / systèmes de refroidissement à haute efficacité et à faible consommation d'eau / intégration de l'énergie hydro-éolienne / biocarburants de nouvelle génération / stockage d'énergie de pompage hydraulique (comme élément clé pour le décollage des énergies renouvelables) / usines de dessalement associées aux énergies renouvelables (y compris les nouvelles technologies de dessalement telles que les membranes) / modélisation intégrée eau-énergie / autoproduction (ex: solaire thermique, solaire PV, éolienne, pompage solaire) / systèmes de conservation de l'eau / réutilisation et recyclage de l'eau / défaillances de l'infrastructure dues à des événements météorologiques extrêmes.

Énergie <> Alimentation

- *Tendances et technologies dominantes ? (Voir les sujets proposés ci-dessous)*
- *Impacts sociaux dérivés / attendus ?*
- *Principaux obstacles à l'adoption ?*

Thèmes : vulnérabilité de la production alimentaire due au changement climatique / efficacité énergétique dans l'industrie alimentaire / protéines végétales / chaînes d'approvisionnement durables / efficacité des ressources et consommation propre / consommation et production alimentaires durables / changement de comportement des consommateurs / gestion des déchets alimentaires / énergie pour les engrais, la mécanisation et l'irrigation.

Alimentation <> Eau

- *Tendances et technologies dominantes ? (Voir les sujets proposés ci-dessous)*
- *Impacts sociaux dérivés / attendus ?*
- *Principaux obstacles à l'adoption ?*

<u>Thèmes :</u> productivité de l'irrigation pluviale, cultures salines, réutilisation des eaux usées dans l'irrigation, écart de productivité au Maroc (possibilité d'amélioration de la productivité) / cultures aéroponiques (cultures à croissance rapide nécessitant peu d'eau et de sol) comme alternative aux biocarburants traditionnels / intensification des cultures / agriculture urbaine / plantes à croissance rapide / impact de la pollution de l'eau sur l'agriculture / capture de données en temps réel par SIG (télédétection) / génie génétique / effets néfastes de l'irrigation / dégradation des terres / impacts des barrages à grande échelle ou des activités minières, insécurité alimentaire due au tirage ou à la salinité de l'eau.

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Annex II. List of participants in the Expert Interviews

NAME	TYPE OF INSTITUTION	INSTITUTION NAME	EXPERTISE
INTERVIEWS IN MOROCCO			
Virgine GUY	**Private company**	GERES NGO (Group for Environment, Renewable Energies and Solidarity)	Morocco Country Director for a climate development NGO, with the focus on energy access and climate change mitigation and adaptation project implementation in Morocco.
Yassine WAHBY	**River Board**	Agence du Bassin Hydraulique du Loukkos	Head of Division at Agence du Bassin Hydraulique du Loukkos (River Basin Agency in the north of Morocco)
Fouad EL YAZID	**River Board**	Agence du Bassin Hydraulique du Loukkos	Director at Agence du Bassin Hydraulique du Loukkos (River Basin Agency in the north of Morocco)
Mostafa STITOU	**University / Research Institute**	Université Abdelmalek Essaâdi, Tetouan	Sound research on water, energy and agricultural issues like water accountings, water-energy nexus and the links with irrigation.
Farida El YOUSFI	**University / Research Institute**	Université Abdelmalek Essaâdi, Tetouan	Experience and relevant publications on analytical environmental chemistry and water analysis.
Mounir NECHAR	**University / Research Institute**	Université Abdelmalek Essaâdi, Tetouan	Agricultural engineer with experience in water planning and management, water scarcity and drought management and environmental flows.

Badredine SOUHAIL	**University / Research Institute**	Université Abdelmalek Essaâdi, Tetouan	Broad research production on analytical method development, simple preparation, protein stability and general environmental issues.
Amas El LAGHDECH	**University / Research Institute**	Université Abdelmalek Essaâdi, Tetouan	Sound research on the water-energy nexus, with the focus on irrigation uses.
INTERNATIONAL INTERVIEWS			
Carlota SANS	**International Organisation**	UNIDO (United Nations Industrial Development Organisation)	Sustainable development and policy expert within the agri-food industry. Track record of +30 projects implemented in the MENA and LAC regions.
Boris BRKOVIC	**International Organisation**	ISWA (International Solid Waste Association)	Technical Coordinator responsible for the full scope management of external projects and partnerships of the International Solid Waste Association. Track record of large projects implemented with focus on Africa and Southeast Asia.
Cassandra PILLAY	**International Organisation**	UNIDO (United Nations Industrial Development Organisation)	Climate change expert working on solutions to decarbonize industries, looking into frontier technologies associated with the fourth industrial revolution and what it can do to accelerate the clean energy transition.
Mahesh YAMPANI	**University / Research Institute**	International Water Management Institute (IWMI)	Experienced water resources specialist with a demonstrated history of working in the research and consulting industry. Hydrologist by training specialized in water chemistry, groundwater and environmental modelling.

Annex III. Information of the Dams in Morocco

Name of dam	Nearest city	River	Major basin	Com-pleted	Dam height (m)	Reservoir capacity (million m^3)	Reservoir area (km2)	Sedimen-tation (latest known) (%)	Irrigation	Water supply	Flood control	Hydroelect. (MW)	Navigation	Recreation	Pollution control	Livestock rearing
Sidi Said Maachou	El Jadida	Oum Er Rbia	North West Coast	1929	29	2	0,08			x		x				
Kasba Tadla	Fqih Ben Sale	Oumer R'Bia	North West Coast	1931	12	0,1	0,004		x							
Mellah	Mohammadia	Mellah	North West Coast	1931	33	18	0,24	55,0	x	x						
Al Thelat	Tetouan	Lao	Mediterranean Coas	1935	36	30	0,2		x			x				
El Kansera	Sidi Slimane	Beht	North West Coast	1935	68	297	1,8	19,6	x	x		x				
Lalla Takerkoust	Marrakech	N'tis	North West Coast	1935	71	96	0,6	27,6	x			x				
Ouazzane	Ouazzane	Bou Déroua	North West Coast	1937	16	0,4				x						
Imfout	Settat	Oum Er R'Bia	North West Coast	1944	50	83	0,875		x	x		x				
Daourat	Settat	Oum Er R'Bia	North West Coast	1950	40	9,5	0,26					x				
Zemrane	Khouribga	Zemrane	North West Coast	1950	20	0,6	0,012		x							
Ait Ouarda	Beni Mellal	El Abid	North West Coast	1953	43	4	0,047		x			x				
Bin El Ouidane	Azilal	El Abid	North West Coast	1953	133	1484	15	6,7	x			x				
Mechra Homadi	Berkane	Moulouya	Mediterranean Coas	1955	57	42	0,285	76,0	x	x		x				
Taghdout	Ouarzazate	Amra	North West Coast	1956	26	3	0,012		x							
Nakhla	Tetouan	Nakhla	Mediterranean Coas	1961	46	13	0,068	46,8		x						
Safi	Safi	Asmine ou Sah	North West Coast	1965	18	2	0,083			x						
Mohammed V	Berkane	Moulouya	Mediterranean Coas	1967	64	725	20	35,4	x	x		x				
Ajras	Tetouan	Ajras	Mediterranean Coas	1969	18	3	0,1		x							
Moulay Youssef	Marrakech	Tessaout	North West Coast	1969	100	197	0,495	11,1	x			x				
Hassan Addakhil	Errachdia	Ziz	North Interior	1971	85	369	1,9	5,7	x	x	x					
Mansour Eddahbi	Ouarzazate	Draa	North West Coast	1972	70	592	4,76	10,6	x	x	x	x				
Youssf Ben Tachfine	Biougra	Massa	North West Coast	1972	85	320	1,375	5,2	x	x						
Idriss 1°	Inaouene	Inaouene	North West Coast	1973	72	1217	42	2,5	x			x				
Sidi Mohamed Ben A	Rabat	Bouregreg	North West Coast	1974	105	1025	2,8	4,5		x						
Ibn Batouta	Tanger	Mharhar	Mediterranean Coas	1977	30	43,6	0,6	12,7		x						
Al Massira	Settat	Oum Er R'Bia	North West Coast	1979	82	2760	14,1	3,0	x	x		x				
Oued El Makhazine	Ksar El Kebir	Loukkos	North West Coast	1979	67	807	4,1	4,2	x	x		x				
Abdelmoumen	Agadir	Issen	North West Coast	1981	94	216	0,75	0,6	x	x		x				
Garde Du Loukkos	Larache	Loukkos	North West Coast	1981	9	4	0,22		x							
Mohamed Ben Abdell	Al Hoceima	Neckor	Mediterranean Coas	1981	40	43	0,386	16,2	x	x						
Timi Noutione	Kela	Tessaout	North West Coast	1981	45	5,5	0,532		x							
Sidi Driss	Demnate	Lakhdar	North West Coast	1984	42	7	0,11	79,0	x							
Ait Lamrabtya	Oulmes	Kanaza		1985	19	0,2	0,004		x							

Arid	Rommani	Arid		1985	20	0,7	0,013		x	x								
Imin Larbaa	Marrakech	Tighizrit		1985	16	0,8	0,019		x									
Kwacem Aval	Settat	Chguigua		1985	12	3	0,02											x
Msakhskha	Oujda	Msakhskha	Mediterranean Coas	1985	20	2,7	0,083											x
Sfa	Ait Baha	Sfa		1985	16	0,6	0,012				x							
Sidi Ali				1985	10	0,1												
Achbarou	Rissani	Gaiz		1986	20	1	0,29		x									x
Agafay	Marrakech	Arissa		1986	28	0,5	0,005		x									x
Akka N'Oussikiss	Boulmane	N'Oussikiss		1986	42	1	0,007		x									x
Akkrouz	Goulmina	Noukrouz		1986	24	0,6	0,01		x									x
Assif Taguenza	Agadir	Taguenza		1986	24	0,4	0,005		x									
Bnismir	Ouedzem	Ouedzem		1986	16	0,9	0,024			x								
Boukerdane	Missour	Boutaaricht		1986	22	0,4	0,008		x									x
Boutaaricht	Rich	Boutaaricht		1986	18	0,7	0,032		x									x
Dkhila	Agadir	Issen	North West Coast	1986	32	0,7	1,335		x	x								
Hammou Ourzag	Bouarfta	Hammou Ourza	North Interior	1986	14	1,6	0,068											x
Hassan 1°	Demnate	Lakhdar	North West Coast	1986	145	273	6,7	3,7	x	x		x						
Kheng El Hda	Oujda	Marbouha	Mediterranean Coas	1986	15	3,8	0,038											x
Si El Miari	Kasbat Tadla	Takhzrit	North West Coast	1986	21	1,1	0,028		x									
Tizguit Aval	Ifrane	Tizguit		1986	18	0,1	0,006				x							
Tlet Boubker	Tetouan	Irhane	Mediterranean Coas	1986	30	2,8	0,076		x									
Ain Koreima	Ain Aouda	Akrech	North West Coast	1987	26	1,3	0,022		x									
Ain Tourtoute	Khenifra	Behaligarane		1987	21	0,9	0,02		x									
Aman Sayernine	El Hajeb	Dfali		1987	16	0,3	0,007				x							
Azib Douirani	Chichaoua	Douirane		1987	15	0,6	0,015			x	x							
Batmat Rma	Taourirt	Ain Hamou		1987	20	0,8	0,02		x									x
Imin Lhad	Tamanar	Zeddir		1987	23	0,4	0,007		x									x
Mouilah	Boujaad	Mouilah		1987	16	0,5	0,013		x									
Ruidat Amont	Sidi Yahya	Rouida	North West Coast	1987	24	2,9	0,046		x									
Boukhalefi I	Tanger	Msaber		1989	20	1,1	0,015		x									
Itzar	Itzer	Oued Tifitchout		1989	30	0,7	0,011		x									
Touiltest	Oued Zem	Touiltest	North West Coast	1989	17	1	0,027		x									x
Allal Al Fassi	Setrou	Sebou	North West Coast	1990	61	81,5	2,5		x	x		x						
Oued Aricha	Ben Ahmed	Oued Aricha	North West Coast	1990	30	1,8	0,026											x
Ras Bel Firane	Oued Amfil	Bel Firane		1990	17	0,3	0,01		x	x								x
Aoulouz	Taliouine	Souss-Massa	North West Coast	1991	79	110	0,51		x		x							
Blad El Gaada	Boufrekane	Boufrekane	North West Coast	1991	30	2,9	0,038				x						x	
Gard de Sebou	Kenitra	Sebou	North West Coast	1991	18	40	0,7		x									
Saboun	Tanger	Saboun		1991	15	1,1	0,027		x									
Sghir	Tanger	Sghir	Mediterranean Coas	1991	15	2,3	0,065		x									

Smir	Tetouan	Smir		1991	45	43	0,325			x							
Tizguite Amont	Ifrane	Tizguite		1991	15	0,3	0,013				x			x			
Agherghise	Buizakarene	Assif Nettella	North West Coast	1992	24	0,3	0,04				x						
Douiss	Boudnib	Douiss	North Interior	1992	21	0,9	0,023		x								x
Essaf	Ghafsai	Essaf		1992	29	1	0,017			x							x
Imaouene	Buizakarene	Imaouene		1992	23	0,2	0,006				x						
Jorf El Ghorab	Ouartzagh	Jorf El Ghorab		1992	29	0,9	0,014			x							
Joumouaa	Tarquist	Joumouaa		1992	57	6,5	0,018			x							
Mahraz	Fes	Oued Fes		1992	17	0,6	0,018				x				x		
Imin El Kheng	Taroudant	Berhil		1993	39	12	0,165		x								
Aggay	Sefrou	Aggay		1994	40	1	0,012				x						
Sahla	Taounate	Sahla		1994	55	62	0,43		x	x							
Arabat	Nador	Arabat		1995	17	2	0,048			x							
Injil	Missour	Taghoucht		1995	36	12	0,305		x	x							
Neuf Avril 1947	Tétouan	Hachef		1995	52	300	1,62			x							
Saquia Al Hamra	Laayoune	Saq. Al Hamra		1995	16	110	3				x						
Al Wahda	Taounate	Ouergha		1996	88	3730	123		x			x					
Sidi Chahed	Mèknès	Mikkès		1996	51	170	1,083		x	x							
Ben Yakhlef	Tétouan	Ben Yakhlef		1997	18	0,3			x								
El Menzel	Taourirt	Oued Za		1997	18	0,2	0,001										
Gharbia	Taounate	Ouergha		1997	22	1			x								
Bouhouda	Taounate	Sra		1998	55	55,5	0,343		x	x							
Bouknadel	Khémisset	Serou		1998	19	1											
Hassan II	Taourirt	Oued Za		1998	83	275	0,775		x	x							
Asfalou	Taounate	Asfalou		1999	112	317			x								
Bab Louta	Taounate	Laoutar		1999	54	37											
Ahmed Al Hansali	Fqih Ben Sale	Oum Er Rbia		2001	101	740			x	x							
Bouhouta	Safi	Bouhputa		2001	19	0,9											
Mokhtar Soussi	Taliouine	Choukoukane		2001	60	50	0,233		x								
Ouled Abbass	Safi	Ouled Abbass		2001	15	0,9											
Moulay Abdellah	Agadir	Tamri		2002	70	110				x							
Had Laghoualem	Rommani	Bridila		2002	19	0,9			x								x
Ait Messaoud	Béni Mellel	Oum Er Rbia		2003	34	13,2			x	x							
Draa El Grara	Safi	Jemala		2003	24	4,3			x	x							
Boubagra	Bejaad	Boubagra		2003	21	1,8			x								x
Baaj	Dar Khebdani	Baaj		2003	16,5	0,45				x							x
Sehb El Kheyat	Beni Guil	Sehb El Kheyat		2003	16,5	0,56											x
Roknet Ennam	Beni Guil	Roknet Ennam		2003	17,5	2,5											x
Oued Namous	Maatarka	Namous		2003	17,6	1,5											x
Ahl Souss	Ait Baha	Izig		2004	49	4,7			x	x							

Douiss Figuig	Bouanane	Oued Zelmou		2004	23	2,35			x	x						x
Sidi Mohamed Ben S	Essaouira	Igouzoulane		2005	60	17			x	x						
Moulay Hassan Bel M	Tetouan	Raouz		2005	49	31			x	x	x					
Tamesna	Ben Ahmed	Zamrine		2005	66	56			x	x	x					x
Reg Aouin Kora	Tilmzoun	Tamlihat		2005	16	1,2					x					x
Kheng Messaoud	Tilmzoun	Boujniba		2005	24	1,3					x					x
Hassar	Ben Yehklef	Hassar		2005	15	2,13					x					
Sidi Said	Midelt	Moulouya		2006	124	400	1,27		x	x	x	x				
Tanafit El Borj	Khenifra	Oum Er Rbia		2007								x				
Touizgui Rem	Assa	Bou Legmaden et Tigzert		2007	18	78			x							x
Al Himer	Ben Ahmed	Al Himer		2008	38,5	14					x					
Tanger Med	Ksar Sghir	Rmel		2008	80,5	25				x	x					
Yaacoub El Mansour	Tahanaout	Nfis		2008	70	70				x						
Takhzrit				2009	28	1,2			x							
El Handak				2009	27	0,1										
El Maleh		El Maleh		2009	49	75										
Chbika				2010	22,5	1,4			x							
Sfeissif				2011	28	20			x							
Ait Moulay Ahmed		Ain Leuh		2011	29	2,4			x							
Koudiat El Garn	Settat	Oued Tamadroust		2012	54,5	33					x					
Taskourt	Assif Al Mal	Assif Al Mal		2012	75	25			x	x	x					
Tiouine		Oued Iriri		2013	18	0,2			x	x	x	x				
Zerrar				2013	73	65			x	x						
Mazer	Settat	Mazer		Incomp.	39	13					x					
Oued Martil	Tétouan			Incomp.	100	120			x	x						
Sehb El Merga				Incomp.	40	6,5			x							
Sidi El Mahjoub				Incomp.	22	1			x							
Sidi Yahya				Incomp.	30	11			x							
Tamalout				Incomp.	61	50			x	x						
Timkit				Incomp.	56	14			x							
Moulay Boucheta				Incomp.	57,5	11,6			x	x						
Lahouar				Incomp.	27	0,86										
Krayma				Incomp.	32	3										
El Ghezoua				Incomp.	22	0,36										
Ouljet Essoltane				Incomp.		510										
M'dez				Incomp.		700										
Dar Khrofa				Incomp.	53	480			x	x	x					
Sidi Abdellah				Incomp.		10										
Ganfouda				Incomp.												

Information on the dam may not be complete of fully precise.

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